JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

FOR THE PROMOTION OF THE MECHANIC ARTS

VOL. CLX, NO. 4 80TH YEAR OCTOBER, 1905

The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, March 15, 1905.

The Telautograph.

BY H. I. ENGLISH.

[This paper includes a brief account of the invention and development of the Gray telautograph, and deals specially with the instrument in its present commercial form.—THE EDITOR.]

Electrical transmission of handwriting has engaged a certain amount of attention ever since telegraphic transmission or printed characters was successfully carried out.

As early as 1886 Cowper and Robertson brought the writing telegraph into a fairly operative form. This instrument was adapted to operate several receivers in series in "reporting" service, where the regular news ticker service was unobtainable or too expensive. The system was put to some use, chiefly in Pittsburgh and vicinity.

The writing was received on a paper tape, advanced at constant speed by clockwork. No pen-lifting device was provided

and the words were connected together by a mark of the pen, making figurework poor. As the characters were formed by the combination of the pen motion and the tape motion, a certain amount of practice and skill was required to produce a legible message.

The electrical features were as follows: Two independent variable currents were obtained from the transmitter; these passed over lines to the receiver where they traversed two electromagnets set at right angles to each other, and so influenced their effect upon a common armature as to cause the receiver-pen rod to produce the motion of the transmitter pencil.

It will be noted that this principle is nearly identical with that of Gruhn's Telechirograph, recently described in the technical press, the main differences being that the telechirograph writes upon a larger field and uses a beam of light, and photographic record instead of a pen with ink record.

Following the writing telegraph, Professor Elisha Gray constructed, at his Chicago laboratory, an instrument which wrote upon stationary paper, and which he called a telautograph. It required four line wires and operated as follows: By means of cords and drums the motions of the transmitting stylus were resolved into two mechanical interrupters in the primary circuits of two induction coils. The relations of the parts were such that a motion of the transmitting stylus amounting to one-fortieth of an inch caused a complete make-and-break at one or both of the interrupters.

The line currents were the impulses produced in the secondary circuits of the induction coils. These impulses passed over lines to two electromechanical escapements in the receiver. By means of cords and drums their motions were combined and caused to act upon the receiver pen. By the use of relays and condensers and a local battery at each receiver the paper was advanced when necessary and the pen lifted from and lowered to the paper. The mechanical difficulties met with in perfecting this instrument were very great, and in the apparatus exhibited at the World's Fair, in Chicago, in 1893, the escapement mechanism was brought to a perfection thought impossible of attainment only a short time before. The writing showed a saw-tooth or step-by-step character, due to the action of the escapements. The instrument was aband-

oned on account of the number of line wires required, limited speed, numerous fine adjustments, and cost and difficulty of manufacture.

In 1893, while still working at the escapement device, Professor Gray patented a variable-current instrument, using two line wires, which worked, in a general way, like the present telautograph. The motions of the transmitter pencil were resolved into two components which were used to vary two line currents, the variable resistances being carbon rods dipped into tubes of mercury. The receiver contained two D'Arsonval movements, to the moving elements of which the pen-arms were attached. Professor Gray never developed this instrument much beyond the laboratory stage, probably on account of his firm belief in the escapement type.

Foster Ritchie, at that time an assistant to Professor Gray, gave considerable attention to this patent and perfected an instrument based on it. He obtained a patent for improvements and has produced an instrument that operates in a fairly satisfactory manner under certain favorable conditions.

The telautograph has been brought to its present state chiefly through experimental work done by, or under the personal direction of Mr. George S. Tiffany, to whom several patents for improvements have been granted. Mr. Tiffany's instrument operates on the variable-current principle and includes a number of interesting features, among them what may be called a straight-line D'Arsonval movement, which is used to operate the receiver.

The operation may be briefly described thus: At the transmitter a pencil is attached by rods to two lever-arms which carry contact-rollers at their ends. These rollers bear against the surface of two current-carrying rheostats, connected to a constant-pressure source of direct current. The writing currents pass from the rheostats to the rollers and from them to the line wires. When the pencil is moved, as in writing, the positions of the rollers upon the rheostats are changed and currents of varying strength go out upon the line wires. At the receiver these currents pass through two vertically movable coils, suspended by springs in magnetic fields, and the coils move up or down according to the strength of the line currents. The motions of the coils are communicated to levers similar to

those at the transmitter, and on these levers is mounted the receiver pen, which, by the motion of the coils, is caused to duplicate the motions of the sending pencil.

Many of the principles and devices in the instruments are of considerable interest. The method by which the variable currents are obtained is the laboratory arrangement for securing a variable pressure from a direct current, constant pressure circuit; that is, the line circuit (of constant resistance) is connected as a shunt around that part of the rheostat between the moving roller and the ground or return. Motion of the roller varies the amount of resistance in series with the line and also the amount in parallel with it and fine graduations are easily obtained, giving smooth motion of the receiver pen. In this way a variable pressure is impressed on the line circuit, giving a variable current. In all the other variable-current instruments, a constant pressure was impressed on line and a resistance in series with the line varied to give the desired variations in current. One result of the shunting method is a better form of rheostat, more easy of construction and handling, in which, also, the heating is better distributed.

The rheostats are wound upon castings of I cross-section, with the turns of wire lying close together on the inner or contact-face. After winding, the insulation on this face is saturated with glue, which is allowed to harden and is then scraped off, taking the insulation with it, and giving a surface where contact is possible on every turn of the wire. This gives a rheostat of a large number of small steps, of good mechanical construction, and of low cost.

The receiver operates with what may be called a straight-line D'Arsonval movement. The moving element or coil is wound upon a copper shell for damping effect. The magnetic circuit is so arranged that one pole surrounds the other, forming an annular air-gap of short length and large cross-section in which the direction of the flux is radial. The field is electromagnetic and is highly excited, to secure uniformity. The coil suspended in the annular space, moves up or down with little friction, as it touches the sides of the space of the core very lightly, if at all. The principle is the well-known one that a circuit-carrying coil, in a magnetic field, tends to place itself

with respect to the field so that the flux enclosed by the coil shall be a maximum.

The current for operating is taken from the ordinary lighting mains, preferably at about 115 volts. Satisfactory operation has resulted with pressures from 80 up to 250. At 115 volts, receiver and transmitter each require about one ampere while in operation. Fairly steady pressure is necessary as the receiver, being in effect a voltmeter, is rather sensitive to sudden changes, the effect being slight distortion of the message.

A master-switch at the transmitter is provided to do all necessary switching of line and power circuits, to make needed changes in connections and to cut off current when not writing. A relay in one of the lines closes the power circuit of the receiver whenever the transmitter at the distant station is switched on, and serves to prevent waste of current when not in operation.

Attached to the master-switch is a mechanical device which shifts the transmitter paper the space of one line of ordinary writing for each stroke of the switch. The relay mentioned controls the electrical receiver paper shifter and, as each stroke of the switch causes a stroke of the relay, the receiver paper is shifted an amount equal to that at the transmitter. The writing is about two inches long and five inches wide, allowing for three or four lines of writing. When filled by messages a few strokes of the switch serve to bring fresh paper into position at both receiver and transmitter.

To prevent switching on of the transmitter while its home receiver is receiving a message from the distant station, an electromagnetic lock is connected in the receiver power circuit, controlled by the relay, and locks the home transmitter in the "off" position until the distant transmitter is switched off. If both transmitters were switched on at once neither station would receive any message; the lock is provided to render this condition impossible.

The ink supply is most important and is arranged for as follows: At the left of the receiver platen is a bottle with a hole in the front near the bottom. When filled with ink and tightly corked the ink does not run out of this hole because of the pressure of the atmosphere. The ink is accessible for the pen

at the hole and the surface of ink exposed to evaporation is small.

The pen is made of a piece of German silver bent double, after the manner of a ruling pen, and makes a uniform line in any direction over the paper. It takes up its supply by capillary attraction, from the hole in the front of the bottle. When the receiver is switched off, retractile springs draw the pen-arms to stops so arranged as to bring the pen exactly in front of the hole in the bottle, and when the pen-lifter armature is released the pen is caused to insert its tip in the opening. Thus a fresh filling of ink is obtained each time the paper is shifted. When not in use the pen rests in the ink, always ready to write.

For the prevention of mechanical shocks to the necessarily light moving system of the receiver, it has been necessary to supply means to prevent the switching on or off of the transmitter, and by that action of the receiver, when the transmitter pencil is "out in the field;" that is, at a position other than that corresponding to the opening in the receiver ink-bottle; as in that case the receiver pen would instantly jump to a similar position. This position is called the "unison point," a term having its origin in the days of the "self-propellor" escapement telautograph. By placing a catch, released only by pressure of the pencil-point upon it, at the transmitter unison point the desired result is accomplished and the transmitter master-switch cannot be switched either "off" or "on" unless the pencil be placed at the unison point and held there until the stroke of the switch is completed. In this case, as everywhere, the apparatus is made strong enough to stand any possible shocks, and then every precaution is taken to prevent their occurrence. Aside from shock to the moving system, these jumps might shake the ink supply out of the pen and prevent the recording of the message.

The pen-lifter is a magnet placed back of the receiver writing platen, and carrying upon its armature a rod adapted to engage with the pen-arm rods and raise the pen clear of the paper when the magnet is energized. This magnet is controlled from the transmitter as follows: Beneath the transmitter platen is a spring contact, opened by pressure of the pencil upon the paper, and closed by a spring when the pencil is raised. An induction coil having an interrupter in its primary circuit is so

connected to this spring-contact that when the pencil is raised the primary winding is short circuited. The induction coil has two independent secondary windings through which the two variable line currents pass before leaving the transmitter. The effect of the induction coil and its interrupted primary current is to induce in the two-line current superimposed vibrations or "ripples" when the pencil is pressed down on the paper and the spring-contact is open. When the contact is closed, by its spring, and the primary winding is cut out, no vibrations are produced in the line currents. In one of the line wires, at the receiver, is placed a relay, upon whose sheet-iron diaphragm armature is mounted a loose contact, consisting of two platinum-silver contacts in series, sealed in a glass tube, to prevent oxidation. A local circuit contains the winding of the pen-lifter magnet and this loose contact.

When the vibrations are present in the line current, due to the pressure of the pencil upon the paper and consequent opening of short circuit of the primary of the induction coil, the diaphragm of the relay is shaken, the loose contact opened and the pen-lifter de-energized, its armature is drawn back by a spring and the pen is allowed to rest against the paper. When there are no vibrations in the line currents due to the raising of the pencil from the paper, the relay diaphragm is at rest and the pen-lifter is energized and the pen is lifted clear of the paper.

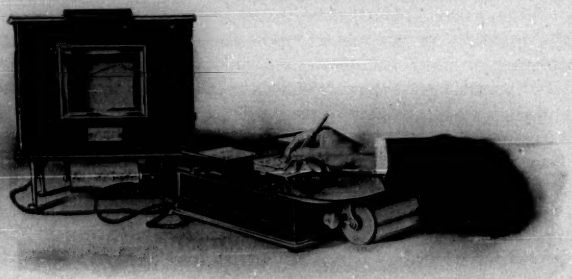
The superimposed vibrations used for operating the pen-lifter have another minor effect. The suspended coils, and through them the entire moving system of the receiver, are kept in a state of very slight mechanical vibration while the pen is on the paper. This aids the flow of ink from the pen-point, assists the pen in passing over any roughness or irregularity in the surface of the paper, and materially reduces friction in the joints and pivots of the moving system, and results in better writing. In some of the later instruments the two relays, that for pen-lifting and that for paper-shifting and power switching, are combined in a single piece of apparatus.

For signalling, a push-button is placed upon the transmitter and a call-bell or buzzer is mounted on the receiver. This circuit is disconnected by the master-switch while a message is being written. Spring reels are attached when needed to roll

up the received messages for preservation and future reference.

The ordinary arrangements for operation are as follows: The instruments may be operated singly, upon a private line having an instrument at each end, or on an exchange system where a switchboard provides for connection. Working in this way, satisfactory writing has been obtained with a resistance in each line wire of 1600 ohms and an operating pressure of 110. Multiple operation can be carried out to a limited extent, three receivers being at present the maximum number that can be operated at once, in multiple, using 110 volts. This allows of placing a supervisory machine upon a line.

Instances in actual commercial use of the arrangements of instruments in Philadelphia are: Provident Life and Trust Co., Corn Exchange National Bank, West End Trust, Tradesmen's



Trust Co., Girard Trust Co., who use the Telautograph to connect from paying teller to book-keeper to ascertain a depositor's balance. C. J. Webb & Co., 116 Chestnut Street, have a line which connects to their warehouse, 148 N. Front Street, for giving orders for shipment of wool. Philadelphia Electric Co. have a line to connect from 10th and Sansom to Second and Arch Streets; this line is used mainly for sending the readings of meters to the book-keeping department.

Strawbridge & Clothier use the instrument to connect from the Superintendent's office to the Auditing Department, for ascertaining a customer's credit. Finley Acker Co. have lines

which connect their three stores, Twelfth and Chestnut, Twelfth and Market and 128 N. Eighth Street, to their book-keeping department, to ascertain the reliability of a customer's credit.

Multiple operation may be resorted to when a third station upon a line desires a record accessible at any time, of what is being sent, as for instance, when one of the officers of a bank desires to know what passes between his book-keepers and paying tellers. On such a line the third station receives all messages and can write to either or both of the other stations should the necessity arise. Such an installation can be seen at the North American Trust Co., New York.

Series operations may be used when several stations are to receive the same message and no response except a bell signal is required, as in sending orders in a hotel or club from dining room to kitchen, pantry, or wine room; in "reporting" or news service, or for bulletin work, such as the announcement of arrival and departure of trains to a number of stations in a large railway station or freight depot.

Recently two such installations, one at the St. Louis Terminal, St. Louis, Mo., the other at the Pittsburgh Terminal of the Pennsylvania Railroad Company, at Pittsburgh, Pa., have been made, and a similar installation at Broad Street Station is planned in the near future.

One of the most important uses for series systems has been found in the U. S. Coast Defense Service, in sending ballistic data, such as range and azimuth of target, or character of projectile, from position-finding stations to the gunners. This is called "fire-control communication," and is installed in the forts of the U. S. Signal Corps. In a paper presented by Col. Samuel Reber on "Electricity in the Signal Corps," will be found a description of the position-finding system and the desired characteristics of a system of communication for sending this data to the guns are stated as follows: "The system that will successfully solve this problem must be simple in construction, mechanically strong so as not to be affected by the blast, as the receivers are placed close to the guns, rapid in operation, and give a character of record that can be read without liability of error." Since that paper was prepared it has been decided that the receivers must be mounted directly on the gun-carriage and can have no shelter other than that afforded by their

own cases. Add to these requirements the facts that the instruments must be cared for by post electricians, and operated by enlisted artillerymen, messages must be visible at night; and the operation must be independent of rain, salt mists, cold, heat, or tropical insects, and it is apparent that no easy problem is presented.

A special type of telautograph has been designed for this service, and has been adopted by the U. S. Signal Corps for fire-control communication.

In this "service telautograph" the pen-lifter controlling the relay is eliminated and the receiver pen-lifters are operated over a third line wire by the transmitter platen switch directly.

Each gun receiver is enclosed in a water-tight brass case, suspended by springs from the gun carriage directly in front of the gunner. The parts are, as far as possible, made "brutally strong," and the construction is as simple as possible.

The desired rapidity of operation is inherent to the telautograph, and accuracy of record is ensured by careful writing and by the use of a "home" receiver, mounted at the transmitter, where the operator can see plainly, which is connected in series with the gun receivers and records the messages as actually sent over the line.

Freezing of ink is prevented by the addition of alcohol; and rain, mists, and insects, as well as the effects of the blast, are shut out by the metal case. A heavy glass window is placed in the case so that messages can be read without opening the case.

A small incandescent lamp inside the case lights automatically when the receiver is writing and may be lighted by pressing a button at other times, thus providing for visibility at night.

On warships there is a somewhat similar service to be rendered and the performance of this should fall to the army type of telautograph.

Commercial service has given opportunity for the installation of a considerable number of private line telautographs in actual use, and at least three of each of the other typical installations are in operation at the present time.

Much of the improvement in details of construction and reliability in operation has resulted from experience gained in

efforts to perfect service of these commercial plants. The experience leading up to the special arm type of telautograph has extended over a period of about five years, and in the present instrument all the requirements, unusually severe as they are, have been successfully fulfilled.

THE VALUE OF THEORY.

That the electron hypothesis is weakening faith in some of our most cherished theories of electrical action cannot be denied; and the time-honored tenets of magnetism are now subject to challenge as a consequence of the researches in non-ferric alloys by Fleming and Hadfield, * * * . In view of this condition, which may be disturbing to the minds of those who do not properly recognize the real function of theory, it is well to remember that established theory should never be held as an article of faith —as is too often done when connected with names of high authority—but considered only as an acceptable generalization on all the facts in existence coming within the range of the theory. To hold any theory as an ultimate explanation of any set of phenomena implies that every fact relating to the phenomena is known—that nature has nothing more to reveal. It is, moreover, a condition of the growth of human knowledge in any department of science, that whereas the advance never ceases in the acquisition of facts, yet the interpretation placed upon series of facts may vary markedly from time to time. The wealth of acquired material does not shrink, but always advances, sometimes rapidly and at other times more slowly. Nevertheless, the theories embracing the facts, and attempting to explain them, often wax and wither in a single decade. It might really be questioned whether in view of the history of mortality in theories it were worth while attempting to find a theory to fit observation, and whether it would not be better to go on accumulating new materials of facts, heedless of their theoretical relations. The value of theory is, however, that it co-ordinates, or at least seeks to co-ordinate, the facts so as to permit of their proper grouping and presentation in natural sequence. Without the aid of theory, knowledge would constantly become more difficult, by accumulation; whereas, with the aid of theory, knowledge may actually grow easier to acquire, from age to age, in spite of the constant accumulation of material.—*Electrical World.*

GERMAN SHIPBUILDING IN 1904.

One of the most important lines of Germany's industrial expansion has been in shipbuilding. Figures transmitted by United States Consul-General Richard Guenther, Frankfort, Germany, show that in 1904 the German shipyards turned out 278 steamships of 210,999 gross registered tons and 256 sailing vessels of 49,712 gross registered tons. At the beginning of 1905 they had under construction 152 steam vessels of 285,539 gross tons, of which 9 were men-of-war of a total of 69,640 tons. The production for 1904 includes 22 steamers and some sailing vessels, of about 20,000 tons in all, built for foreign account.

REINFORCED CONCRETE RAILWAY TIES.

An interesting use of cement is a method of manufacturing railroad ties recently introduced on the Elgin, Joliet & Eastern Railway. These ties are manufactured under a design originated by R. B. Campbell, general manager of the company, Joliet, Ill.

The tie is 8 feet 6 inches long and 6x7 inches in section, with beveled edges, except under the rails, where it widens to 10 inches for a distance of 8½ inches on either side of the center of the rail. The corners of this widened portion are also beveled to meet the body of the tie. Reinforcement is furnished by two-inch wrought-iron pipe, scrap boiler tubes being utilized for the purpose. Two-seven-foot lengths of these tubes are used for each tie, placed side by side. The tubes are surrounded, sides and ends, by a single thickness of poultry netting. On the center line of the tie below each rail, and parallel thereto, is a 6x8 inch plate of heavy wire netting inserted through specially-punched openings in the pipes. The rail is held to the tie by beveled clip washers and a single U-bolt placed obliquely to the longitudinal center line. A metal plate is imbedded in the tie under the rail.

Very satisfactory tests were made with a number of these ties on a testing machine, and 140 were placed in use, which have been in service from nine to thirteen months. Of these ties nineteen failed in service, but investigation showed that the defects were caused through imperfect mixture, there having been considerable loam mixed with the sand in making the concrete. The results, however, were regarded as sufficiently satisfactory to warrant the manufacture of 1000 more of the ties, which are to be placed in the track of the Chicago, Lake Shore & Eastern Railroad, where the traffic is very heavy. Mr. Campbell states that the ties can be manufactured and sold at a cost of $1.50 to $1.75 each.—*Iron Age.*

SMOKE-PREVENTING DEVICE.

A new smoke-preventing device for boiler furnaces has been invented by Mr. J. S. Pearson, of Glasgow. The system consists of discharging a combination of steam, air and producer gas into the furnace. The three elements are combined and discharged through nozzles fitted to short pipe connections. The resulting chemical action releases the hydrogen in the steam, and combines the oxygen with the carbon in the fuel. The decomposition of the supplied gases is thus completed, and, by combining with the fuel gases and the resulting new gases thus produced, creates great heating power, emitting heavy smoke. The latter, however, decreases in volume toward the tubes, in which there are only flames, and is completely consumed before it reaches the chimney. The steam pressure does not vary with the stoking or cleaning of the furnace, and no ashes or clinkers are formed. The system can be applied to any type of boiler.—*Scientific American.*

ELECTRICAL SECTION.

(Stated Meeting, held Thursday, March 30, 1905.)

The Alternating Current Generator.

By David B. Rushmore.

[This article is substantially a historical sketch of the origin, development and present status of this important class of electric generators.—The Editor.]

The dynamo dates from the discovery by Faraday, in 1831, of the law of electro magnetic induction. The previous discoveries of Oersted, in 1820, regarding the relative positions of a permanent magnet and an electric current, and of Arago and Sturgeon of the possibility of making magnets from pieces of soft iron by passing an electric current around them, led Faraday, in an unparalleled series of experiments, to discover that important law, and on September 4th, of that year, was first coined the expression "lines of force."

Faraday's disc generator, constructed in 1831, was an experimental unipolar and is of interest as being the first dynamo electric machine. The early development of the dynamo consisted of many modifications of magneto generators, and it was about 1856 that the first commercial use was made of such apparatus, when the embryo of our present arc lamp was supplied by current from a machine built by the Campagnie de l'Alliance, which had been developed by VanMalderen and Nollet. This installation was in the lighthouse. Until 1876 there was a large amount of work done in the development of dynamo machines, most of which were, however, for the generation of direct current and concerned with the work in which are associated the familiar names of Siemens, Wheatstone, Pacinotti, Wilde, Gramme, Lontin, de Meritens, Brush, Weston, Edison, Hefner-Altenech, Ganz and Schuckert.

What might justly be called the first practical alternators were those built by Gramme, between 1876 and 1880. These are

internal revolving field generators with direct-connected exciters, and were demanded by the desire to have both carbons of the Jablochkoff candles burn evenly, which could not be done with the direct current machines then in use. The armature winding is stationary and external, but is the same as the previously well-known Gramme ring construction. The armature is wound with four separate phases and the earlier machines have eight poles on the field and eight sections on the armature. The corresponding coils in the different sections were connected in parallel or series, as was desirable. It was with these machines that the term "exciter" was first used. The special interest of these machines to-day is the fact that they were of the internal revolving field type with a polyphase armature winding and having direct connected exciters.

Following the Gramme machines we have a development of alternators by de Meritens, Hefner-Alteneck, Ganz, Schuckert, Zipernowski & Deri, and, in more recent years, such machines as designed by Kapp, Mordey and Ferrenti.

The first machine used to any extent in this country was developed about 1886-7. It consisted of a stationary external field with inwardly projecting pole pieces, the cast-iron pole pieces and yoke being cast together. The pole face was beveled slightly at the armature surface, but was not extended beyond the pole core. The internal revolving armature consisted of discs built up directly on the shaft. There were six ventilating holes running lengthwise on the shaft but none at right angles thereto. Wooden pieces were secured to the ends over which the flat pancake coils were wound, the ends being bent back at right angles from the cylindrical surface. Wooden pieces were also placed in the center of the flat pancake coils, and later the same were placed between the adjacent coils. The core was covered with insulating material on which these wooden strips were fastened, being held by screws, which passed through the insulation into the iron core. After the coils were wound by hand on the surface of these machines, another covering of insulation was placed around the armature, which was held in place by bands of piano wire, and on the ends by end bells. These machines possessed excellent regulating qualities, good wave form, and good ability to radiate heat. They were, however, very easily injured, and the entire winding

could be stripped from the armature by a piece of metal falling thereon or by the wear of the bearings, allowing the armature to strike the pole pieces.

These early machines were all for 15,000 or 16,000 alternations and were, of course, single phase. The pulsating armature reaction from these alternators caused the pole pieces to heat, and the first change was to cast laminated poles into the field yoke. The next change was to make a toothed armature with one tooth per pole and one armature coil per tooth. These armature coils were machine wound and were insulated separately from the core. They were drawn beneath the projecting top of the teeth and were held in place by a wooden wedge driven between the adjacent coils. Brass shields fitted over the projecting ends of these coils, completly protecting them from the possibility of external injury. These iron-clad armatures were a great improvement mechanically, and it was possible to subject them to very rough handling without injury. The concentrated winding gave poor regulation, a bad wave form and poorer heating qualities than the smooth core type. The considerable pulsation of magnetic reluctance caused heating. The quickness and ease of repair, however, made these machines a decided improvement over the old ones.

There were a considerable number of modifications of both the smooth core and toothed machine with regard to compounding. In some cases an auxiliary winding was placed on the armature and the current therefrom taken through a two-part commutator to either the main or auxiliary field. In other cases, the main current passed through a series transformer, either consisting of the arms of the machine itself or a separate transformer external to the armature. From the toothed form, a polyphase machine was developed known as the Plus 2 type, in which the revolving armature had two teeth more than were poles on the field. Taps led into the armature at points 90° apart and gave the desired quarter-phase relation of the current. The next step was to distribute the winding in many small slots, as is now done. This allowed the use of machine-wound coils, which were easily placed on the armature, and were held in place by wedges passing over the slot. With this winding, better regulation and better wave form were obtained, as well as improved ventilating qualities. The sup-

porting arms of these armatures were used for series transformers and by means of a two-part commutator, the machines were compounded. Radial ventilating ducts were also introduced, and about this time the use of oil rings instead of the oil drip became general. The revolving armature with a distributed winding was built in many sizes and with a considerable variation of mechanical construction.

The demand for higher voltages led to the practice of building the armature external to the field and revolving the field. This allowed the armature circuit to remain unbroken, the only sliding contacts being those for the low voltage field excitation with carbon brushes on cast-iron rings. It also allowed the armatures to be wound directly for voltages as high as 13,200. The field coil is made of copper strip wound on edge, making a large saving in the amount of material necessary for this part, and so making the field coil practically indestructable by heat. Simultaneously with these improvements, a great change has taken place in the insulation used for armatures and the use of oil in some form having become the best practice.

NIAGARA FALLS GENERATORS.

The recent development of alternator design is well shown in the different types of machines which have been furnished the various power stations at Niagara Falls. These machines have been so frequently described that only the points of particular interest will be touched upon.

The original design consisted of the umbrella type external revolving field supported from the top of the shaft. This gave the advantages of combining the fly-wheel with the revolving field and with having the centrifugal force of the poles in opposite direction to the magnetic pull. It also relieved the bolts holding the poles of any strains due to centrifugal force. The revolving field ring was forged from an ingot of compressed nickel steel without a weld, and the poles were solid steel castings held to the rim by bolts. The field coils were held in place by the projecting tips of the pole. A rectangular wire was used in the field coil, which was wound up in solid form and was not ventilated. The collector was placed on the upper end of the shaft and a bridge structure ran over the machine in

order to give access to the collector and bearings. The armature slots were nearly enclosed with two conductors per slot and insulated with material, which was largely mica. The bolts clamping the armature iron passed through the laminations which were ventilated with six one-inch ducts. The ends of the armature winding were left unsupported. On these machines thrust bearings were used as the direction of the pressure on the vertical shaft varied with the load.

The second lot of machines were made by the same manufacturers as the first, but a number of changes were introduced which experience had shown to be desirable. The nuts on the field ring were sunk into the metal. The field coil was very much changed, being wound with a number of layers of copper strip wound on edge, and the whole being well ventilated with ducts through the winding and holes cored into the bobbin. The field coil insulation was largely mica and shellac. In the armature twelve half-inch ventilating spaces were used instead of six one-inch, as in the first machine. The bolts clamping the iron did not pass through the laminations and much better work was done on the punchings, so that less finishing of the slots by filing was required and in this way the heating considerably reduced. The slots were made more numerous and smaller, so that there was but one conductor per slot and the armature winding was reduced 15 per cent. With this reduction came also a reduction in length of air gap from one inch to three-quarters of an inch. Like the first machine, the second had also very bad regulation, which was at that time considered advisable as giving the small cross currents and also as placing an automatic limit to the current output of the machine. The ventilation of the first machine had not taken place as expected and drag hoods were placed on the revolving part of the second machine. The armature was also cooled by means of circulating water in heavy copper tanks placed back of the laminations.

The third machines were built by a different manufacturer, and were considerably changed in design. The purchasing company, however, demanded that in general appearance and arrangement that they conform to the previous types. The collector rings were placed below the armature and the bridge over the machine was omitted. The regulation was made very much better than in the old machines. The armature coils were ma-

chine wound and consisted of rectangular cable placed in open slots with two coils per slot. The poles, instead of being solid, were laminated and the load losses thus materially reduced. The method of ventilating was also entirely changed, so that the air was drawn into the center of the machine from below and forced out at holes in the upper part of the revolving ring.

The fourth type of Niagara machine was made by the same manufacturer as the third but the type of machine was entirely changed. In this generator, the internal revolving field was used and while this choice was due to the development which had taken place in this style of machine it was allowable in particular because of the improvements made in water wheel governors, which necessitated a smaller fly-wheel capacity. Numerous ventilating ducts were placed in the armature. The slots were open and contained two conductors of standard copper cable. The ring of the revolving field is built up of laminated steel sheets and the poles are built up separately of the same material. These are then held in place in the field ring by dove-tails and keys. The armature coils are supported on the ends outside of the laminated iron to prevent any binding effects due to short circuits or heavy currents. In other respects, the generators are all standard revolving field type of construction.

The fifth Niagara machines are double the output of the previous ones, or 7,500 K.W. each. The mechanical structure of the armature frame differs somewhat from the previous machine, but in general the variation is simply one of size. In this machine the solid bar is used for the conductor in the bottom of the slot and a stranded cable, which is passed through the vacuum japan treatment, for the conductor at the surface.

In this country modern types of alternators are divided into two distinct classes, the inductor type and the revolving field type. The revolving armature with external field is still used to some extent. Descriptions will be given of the inductor type alternator as developed and manufactured by the Stanley Elec. Mfg. Co., and of revolving field generators made by the same concern, illustrating the engine type and coupled or water-wheel type. Also, a brief description of modern forms of turbo-alternators.

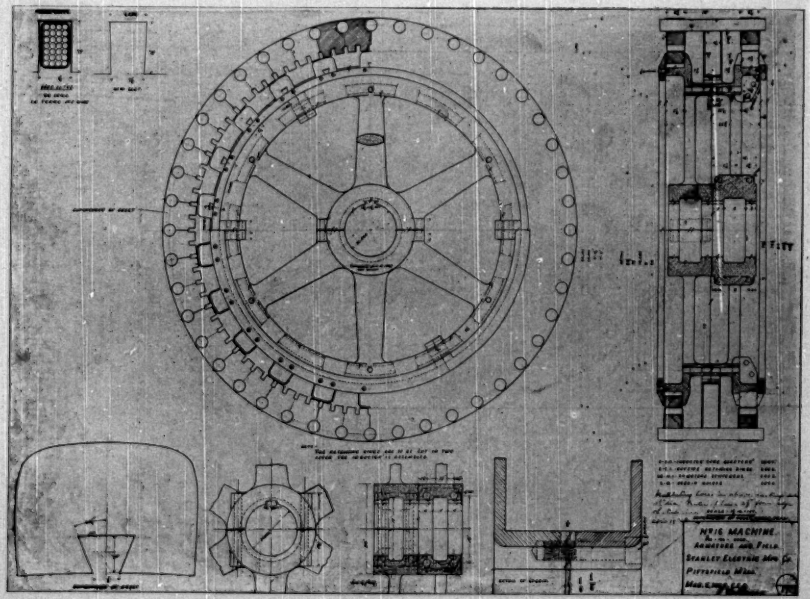


Fig. 1. S. K. C. inductor alternator, engine type, 300 KW.—182 R. P. M. 8000 alts. Winding on armature not shown. Details of slot, field bobbin, inductor punching, and hub.

INDUCTOR ALTERNATOR.

The inductor alternator was developed in this country about twelve years ago, and was at that time decidedly superior to any other machine on the market. The mechanical construction is clearly illustrated in Figs. 1, 2, 3 and 4. These machines are made either engine type, coupled or belted, depending upon

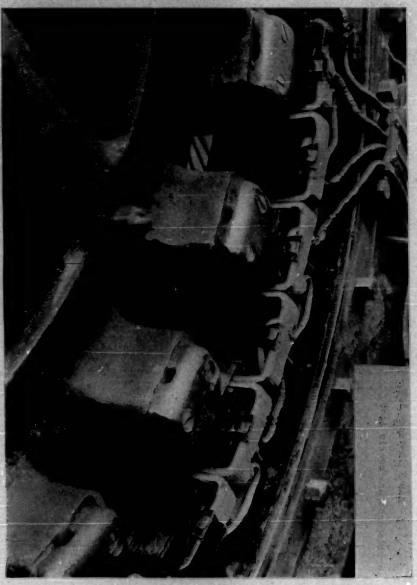


Fig. 2. No. 16 machine, 843. Coil clamps and connections.

the conditions. A considerable variation in mechanical construction exists in each type. The armature frame may either be made of cast-steel shell or tie-bar construction, depending upon the size of the machine and the output per pole. Where kilowatts per pole exceed a certain figure, a limited peripheral velocity may necessitate the use of a cast-steel shell. In the standard tie bar construction, the external stationary armature

is supported by four cast-iron rings which are parted in either an horizontal or vertical plane. The armature laminations are held between the bars on outside rings and are supported on tie bars which connect the cast-iron rings as shown, while supporting the active iron, and, also, act as part of the magnetic circuit of the armature, although the magnetism of these bars undergoes no variation. Half of the bars butt against the outside rings, as shown. Between the two metal rings is a pipe

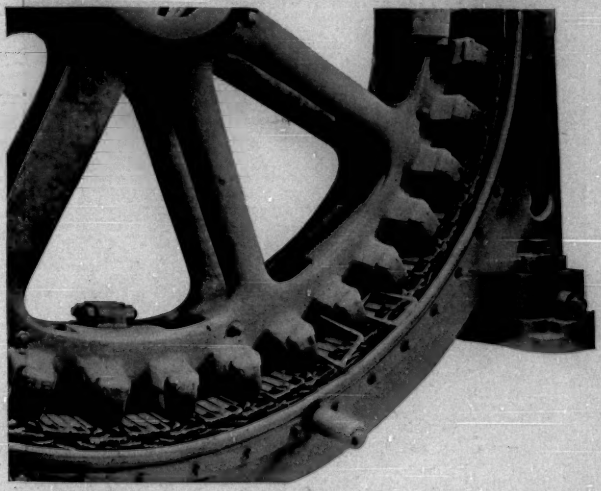


Fig. 3. S. K. C. inductor alternator showing method of removing armature coil.

washer which fixes the distance between these rings. The outside rings in some cases have the shields to protect the armature coils cast in one piece with the ring. In other cases the shields are separate and are fastened by screws. It is seen that the space between the two center rings is but partially occupied by the magnet bars and that a large amount of space, affording easy egress for the air circulated by the revolving inductor is offered, thus giving excellent opportunities for ventilation of field coils and inner ends of the armature winding. The laminated iron in these machines consists of the best obtain-

able quality of sheet steel, made according to rigid specifications, which is afterwards punched out at the shop and thoroughly annealed and japanned by special processes, the development of which is the result of many years of experience. On the ends of each section of laminated iron are sheets of much heavier rolled plate, called stiffeners. These keep the laminated sheets in shape and prevent their spreading apart.

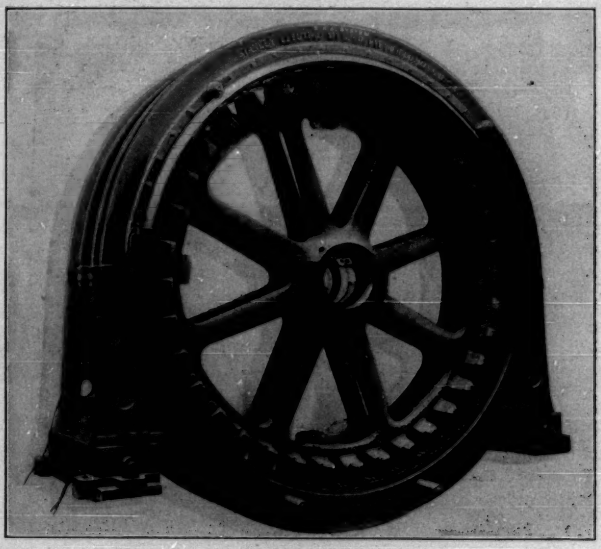


Fig. 4. S. K. C. Indicator Alternator Complete.

The inductor alternator has but a single field coil and this is supported on the inside of the armature structure and does not revolve. The coil consists in the larger machines of a flat copper strip wound inside a brass bobbin, the sections of winding being separated from each other by a wide ventilating duct passing radially through the center of the coil. The strips are insulated from each other by means of oil cloth and the whole winding is insulated from the bobbin by means of specially pre-

pared insulating material. The winding of the field coil is thus seen to be well protected from any possible mechanical injury and to be exposed to excellent ventilation on the sides of the coil and also through the center by a current of air set up by the skeleton revolving mass known as the inductor. The armature winding is placed in slots in the laminated iron and is held by either clamps on the ends of the coil, as in some of the old machines, or by wooden wedges across the top of the slot in the latest types. The armature winding is in almost all cases what is known as the concentrated winding. This gives a firm coil with very short ends, needing no support on the ends of

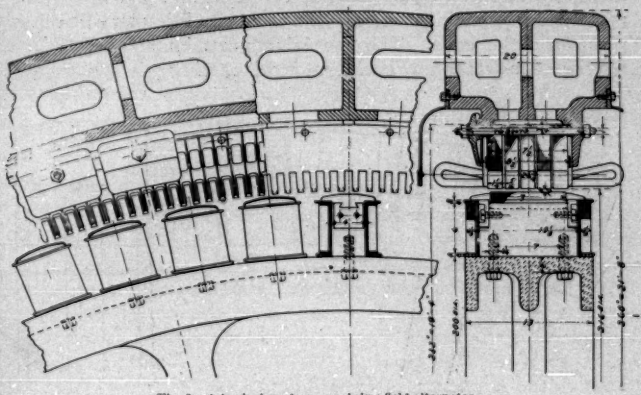


Fig. 5. A typical modern revolving field alternator.

the coils to prevent a bending effect from short circuits. In the larger machines, the armature coils can be removed without disturbing the machine in any way. It is usual to wind the armature with two coils per slot, although certain cases arise in which the one coil per slot arrangement is necessary. The entire armature winding is accessible for inspection when the machine is not in operation and in a way not possible with any other type of machine. The armature winding consists of either wire, strip or stranded cable wound on suitable forms and properly insulated. Where stranded copper cable is used and in all other cases where it is advisable, the winding is given

a vacuum compound treatment which completely fills the interstices of the coil with an insulating japan. This is then pressed into shape and baked so that a uniform solid structure results which cannot be injured by vibration, and which is practically indestructible under such conditions of operation as should exist. These machines may be wound for one, two or three phases, and in the latter case the winding may be for either a star or delta connection. In the insulation of the armature coils, the best and most recent type of oil cloth insulation is used, no micanite being permitted in any part of the coil. Such oil insulation if not subjected to too great a temperature remains for years in practically the same condition as when first placed on the coils. The revolving part, known as the inductor, consists of a skeleton steel casting on which are

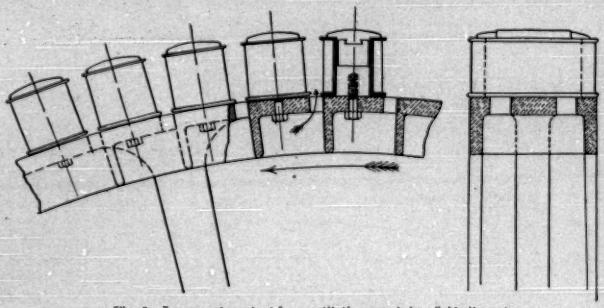


Fig. 6. Improved method for ventilating revolving field alternator.

mounted pole and projections of laminated steel. The external magnetic part of this structure is mounted upon arms and held in the usual manner, and the castings are sub-divided in a variety of ways as best suited to the particular machine as regards the convenience of handling. The central part of the revolving casting is cored out at intervals around the circumference giving one-third of the space in ventilating holes and about two-thirds of solid metal, which arrangement affords the best possible ventilation for the field coil, allowing a blast of air to be thrown against the three sides and forced through the center ventilating space. The rims on which are mounted the pole laminations are cut away between the polar projections in

the later machines. This style of construction, known as the skeleton inductor, allows the armature coils to be easily removed from the larger machines, affords the best possible ventilation and considerably improves the electrical characteristics of the machine with regard to exciting power and regulation, the actual leakage in this type of machine being reduced to approximately 5 per cent. The pole is so formed as to give a magnetic field varying as a sine function of the angle from the center of the pole, which, with the concentrated winding, gives a sine wave of E.M.F. This is an important feature of the inductor alternator and is very difficult to obtain in the revolving field types except with distributed windings. The peculiar electrical operation of this machine is that the flux through the armature pulsates through the armature coils and swings through a certain angle with respect to the armature iron. This allows the use of high densities in the laminated iron without causing heating of the same.

The regulation of the inductor alternator can, of course, be made anything desirable, and, in comparing this type of machine with that of the revolving field alternator, any slight difference in weights may not necessarily mean a similar difference in cost.

In comparison with revolving field machines, the inductor alternator possessing the same efficiency will have a higher armature copper loss and a lower iron and field copper loss. This accounts for high efficiencies at light loads and the fact that the iron in the inductor alternator armature heats but little prevents local rise of temperature in the armature coils.

The characteristic points of this type of machine are as follows: No revolving wire; no sliding contacts; a single field coil; the field coil entirely protected from mechanical injury; the possibility, in larger sizes, of removing the armature coil without disturbing the machine; the small exciting power necessary; the sine wave of E.M.F. with concentrated winding; the proportionately short length of idle conductor in the armature; the unequaled ventilation of armature winding; the absence of any necessity for supporting the armature coils at the end, and, in general, the machine demanding the minimum of care and attention.

REVOLVING FIELD ALTERNATORS.

A typical modern revolving field alternator is shown in Fig. 5. The active material of the external stationary armature is supported by a cast-iron box frame. Armature frames are made in a large variety of styles and sections abroad, but in this country the section shown may be taken as standard. The frame may be divided either horizontally or vertically, and in some of the larger machines is divided into a greater number of parts to facilitate shipment and erection. The box form used gives the best utilization of the material and affords an easy means for ventilating the armature laminations.

These laminations are held by dovetails cut into ribs cast on the armature frame, which ribs run parallel with the shaft of the

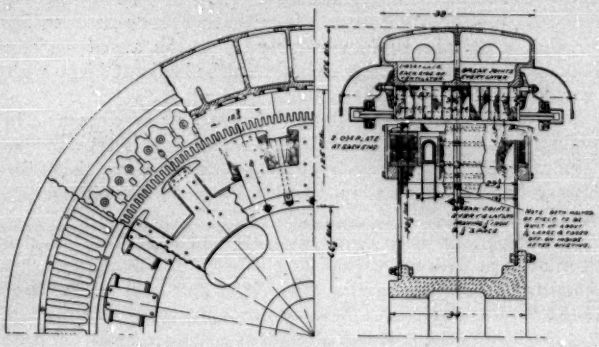


Fig. 7. 5000 K.W. water-wheel type revolving field alternator.

machine. There are also numerous methods for supporting the laminations but this method of dovetail suspension is the most substantial and best. The laminations are divided lengthwise of the machine by many ventilating ducts which allow the free passage of air from the revolving field and are held together by retainers at each end, clamped by bolts passing entirely back of the laminations. This laminated iron is punched, annealed and japanned in the same way as previously described, and its proper manufacture is one requiring great knowledge and skill to obtain the best results.

The armature coils are machine-wound and are completely

insulated before being placed in the open slots. The use of open slots is of great advantage in machines wound for high voltages, as it allows the complete insulation of the coil before it is placed on the machine, and with the oil cloth insulation used where the oil is brushed on each wrapping of cloth and separately baked, the insulation of the entire coil consists of a large number of coatings of an oil film, each complete in itself.

Stationary armatures allow the electrical circuit to be unbroken, which is of great advantage in high voltage machines.

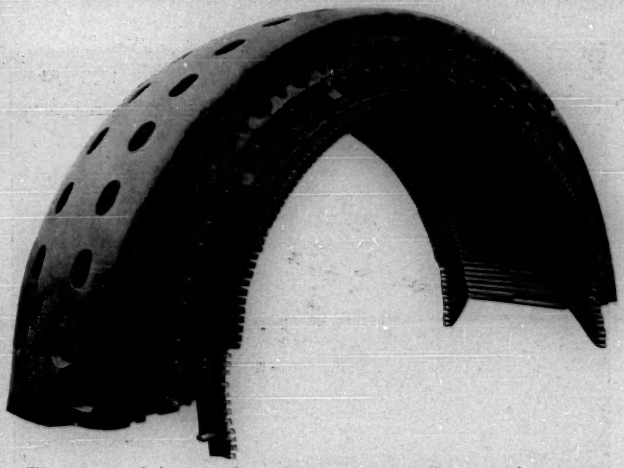


Fig. 8. Upper half of armature frame without end shields, showing method of supporting end connections.

Most revolving field alternators have a distributed winding giving two or more slots per phase and by proper beveling of the pole a sine wave of E.M.F. is obtained. The greater the sub-division of the winding, the better the wave form, and the better the opportunities for dissipation of heat.

The proportionally large amount of space occupied by insulation in high voltage machines limits the possibilities of winding distribution from both mechanical and commercial considerations. Open slots allow the coils to be machine wound and be subjected to vacuum compound treatment and completely in-

sulated before being placed in the machine. With cable conductors this is almost a necessity in order to obtain firm coils and to properly insulate the strands.

High voltage machines necessitate good insulation between the conductors in a coil, as well as between the conductors and iron, a matter not always sufficiently emphasized. By completely insulating the coil before placing it in the slot, this may be accomplished, and in high voltage machines, especially those used as synchronous motors, it is a very important factor.

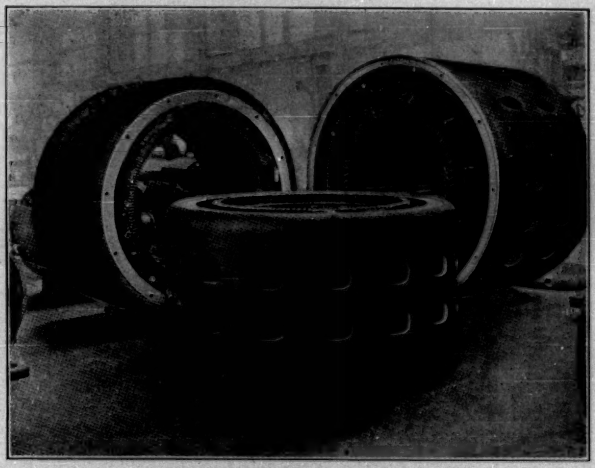


Fig. 10. Stationary armatures for turbine-generators.

Open slots in general necessitate laminated pole pieces, which are, however, of advantage both from a standpoint of symmetrical construction and in preventing an increase of iron loss under load, even though there may be no Focault losses in a solid pole piece on open circuit. Laminated poles allow a quicker response in voltage to any change of excitation.

Poles are fastened to revolving field rings in a large variety of ways. Where the poles are separate from the ring, they are usually held by bolts which enter keys running lengthwise

through the laminated poles in machines of comparatively low peripheral speed, and where the speed is high the laminated pole is dove-tailed and keyed into the ring.

The development of the revolving field alternator brought with it the edge wound copper strip field coils, one of the great advantages of this type of machine, and the manufacture of which illustrates a high development of machine-shop practice.

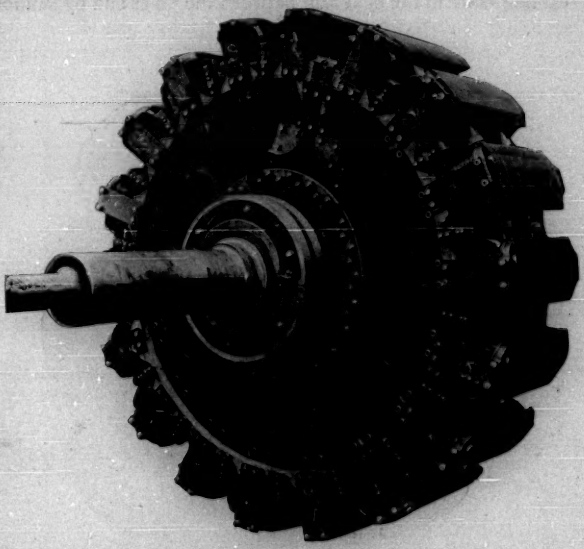


Fig. 9. Revolving field showing details of mechanical construction, illustrating careful consideration of stresses due to centrifugal force.

This strip-wound field coil is of excellent mechanical structure, which cannot get out of shape and which is in very little danger of injury from over-heating, the external surface of the coil being entirely exposed to the air, it being impossible for any local rise of temperature to take place.

The proximity of the field coil to the armature surface acts as a damping device and is in most cases sufficient preventive against hunting troubles.

Solid field rings are in this country universally made of steel and made cast in one piece with the arms and hub, or the latter may be made of cast-iron bolted to the field ring.

The ventilation of the revolving field alternator is somewhat inferior to that of the inductor, and to overcome this a number of methods of construction are used. One of these consists in casting holes in the field ring between the poles and by suitable end rings and cross-webs which act as fans. Fig. 6.

Engine-driven revolving field alternators of large output,

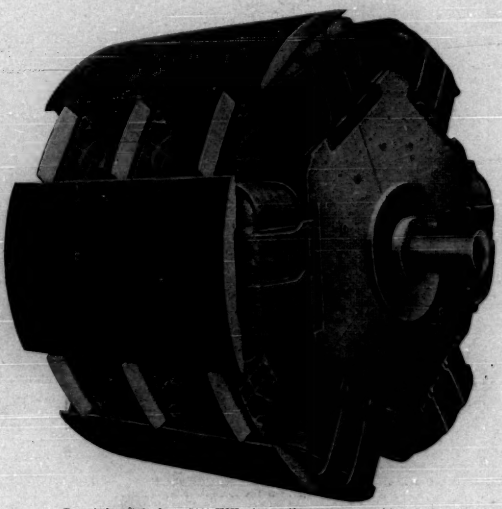


Fig. 11. Revolving field for a 5000 KW. alternating current turbine generator.

especially for the higher frequencies, are often of such dimensions that the revolving field and fly-wheel can very suitably be combined. In such cases the fly-wheel is usually built up of steel plates.

WATER WHEEL GENERATORS.

The use of heads ranging from 1,500 to 2,300 ft., and the demand for units of large output, in many cases 5,000 K.W.,

has led to the development of a water-wheel type of generator, machines and the standard revolving field generators is princi- Such generators must be built to stand an increase of speed of

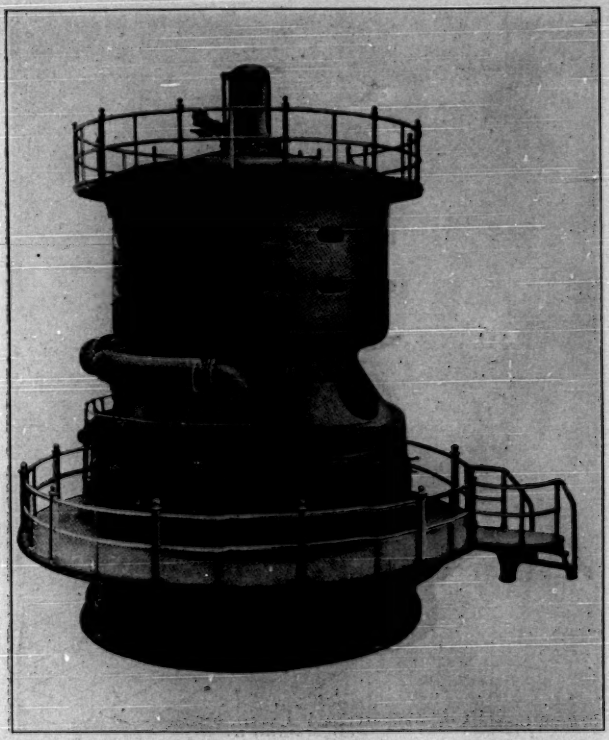


Fig. 12. 5000 KW. Curtis steam turbine direct connected to 5000 KW. three-phase alternating current generator.

something less than 100 per cent., and for this reason the mechanical design takes precedence over the electrical.

The difficulty of hauling these machines for distances up to forty miles to inaccessible power house locations and over bad

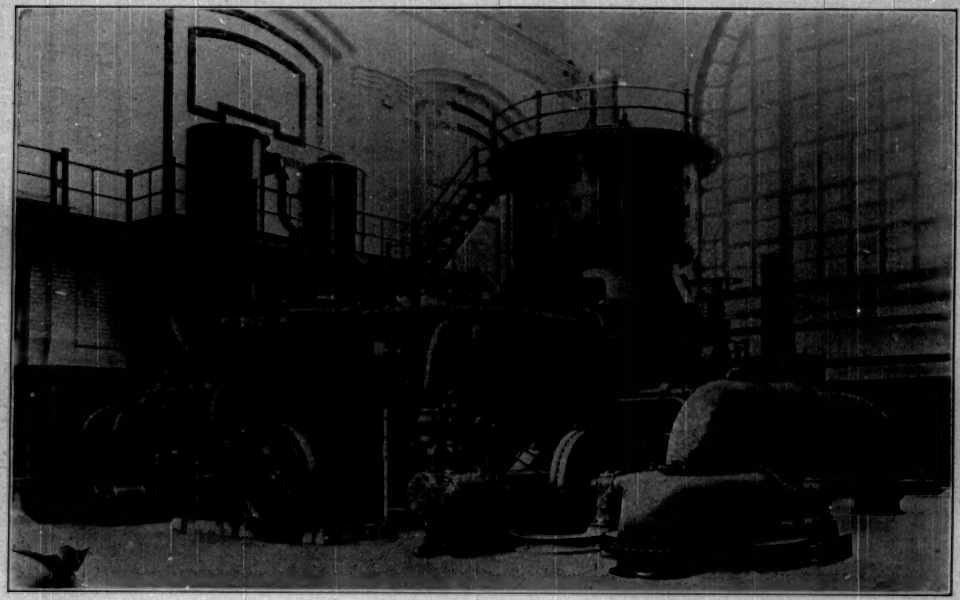


Fig. 13. 5000 K.W.Curtis turbine set with auxiliaries.

roads often influences the mechanical design. An illustration of a machine designed for such conditions is shown in Figs. Nos. 7, 8, 9. This machine was built by the Stanley Electric Mfg. Co. for the California Gas and Electric Corporation, and is a 5,000 K.W. three-phase revolving field generator, running at 400 revolutions and giving 2,400 volts, which voltage is raised by transformers to 60,000.

The stationary armature is a more or less standard construction, except that the weight is reduced to a minimum and the details of every part are most carefully designed in order to make the structure as light as is consistent with necessary strength. The revolving field is of novel construction. The ring and poles are built up of laminated steel sheets, each punching covering two poles and the section between them. In one punching the pole part on one end extends to the air gap; on the other to the bottom of the pole tip. These punchings, $\frac{1}{8}$" thick, are built up in pairs. In this way the resultant structure gives a solid pole while the space between the poles consists of alternate spaces of $\frac{1}{4}$" air gap and the same amount of laminated iron. The field coils are cemented into one solid structure and each individual coil, as well as every separate part of the revolving field, is carefully weighed and balanced. The revolving field ring, built up of laminations, is mounted on the hub by steel end plates, as shown, and is divided into two parts to facilitate transportation by the insertion of two plates in the center, which are similar to the end plates, except for the connection to the hub. After the field coils are placed on the pole, the tips, which are inserted between the alternate laminations, are then put in place and bolts running lengthwise through these tips and the alternate projecting pole pieces, passing also through retainers over the ends of the field coils and holding same in place.

TURBO-ALTERNATORS.

In turbo-alternators, the considerations of the mechanical design are of first importance, and the difference between these machines and the standard revolving field generators is principally one of comparative output and speed, and of methods and devices for supporting the structure under the necessarily great mechanical strains.

Laminated steel is a material of known strength which can be relied upon, and, therefore, is largely used in the construction of the revolving field for turbo alternators. The central ring is built up of these steel sheets and so arranged that the poles are built up and riveted separately, and introduced endwise into the ring structure through proper dovetails and are held firmly in place by keys. The unbalanced component of centrifugal force at right angles to the side of the field coil is taken into consideration by placing proper wedges between adjacent coils. Straps passing over the coil ends securely hold these parts in place. Other types of turbo alternator construction are used, but that shown in Figs. 10, 11, 12, 13, may be taken as representative of the vertical type used in this country in connection with the Curtis turbine.

ALLAYING THE DUST NUISANCE ON HIGHROADS.

For some time past experiments have been carried out in England with several media such as westrumite, and so forth, for overcoming the dust nuisance on the high roads, which is created more especially by automobiles. These materials, however, have proven only partially successful. The results of some later experiments in this direction which have been carried out in Liverpool were recently described by Mr. A. Lyle Rathbone, deputy-chairman of the Liverpool Health Committee in a lecture at Liverpool. The surface of a selected roadway was coated with creosote oil mixed with resin. This mixture gave the cleanest and nicest appearance, while the surface coated with ordinary petroleum was the least lasting. Next in order came mixtures of creosote oil with tallow, and hot creosote oil. Heavy coal tar waste oil lasted rather longer than the creosote oil, and was very much cheaper. Considering the experiments as a whole, the result would seem to point to eventual success with the use of some classes of oil in the place of water on macadam roads.—*Scientific American.*

EFFECT OF HIGH TEMPERATURE ON THE STRENGTH OF STEEL.

Professor Bach has made some experiments to determine the effects of high temperature on the strength of steel, using groups of four bars each. The temperature of the testing of the several groups were: Atmospheric, 390, 570, 750, 930 and 1020 degrees F. On one bar the test at ordinary temperature showed a strength of 54,000 pounds per square inch and an elongation of 26,3 per cent. The strength appeared to increase with rise of temperature, until at 750 deg. the figure stood at 60,300 pounds, while above this temperature the strength decreased rapidly until at 1020 degrees it was only 26,000 pounds per square inch.

CHEMICAL SECTION

*Mica and the Mica Industry.

By George Wetmore Colles.†

[The subject is treated in eight principal captions: Mineralogy, geology, geographical distribution, history, mining, uses, statistics and conclusions. The treatment is industrial rather than theoretical or scientific, and aims at setting forth the present, past and probable future of mica-mining in this and other countries. The first instalment dealt with the characteristics of the various species of mica. The present part deals with the geology of the micas.—The Editor.]

II. GEOLOGY.

Micas of the perissad class (as above indicated), are found in or derived from igneous, that is to say, intrusive or metamorphic rocks. They are the commonest of minerals, common in the sense of being widely distributed, though constituting but a relatively small proportion of the rocks in which they occur. These micas constitute the most conspicuous element in granites, and in most schists and gneisses, as well as in that form of intrusive rock known as pegmatite.

The artiad micas, on the contrary, do not occur (unless possibly in minute crystals of the ferrous kinds) in igneous rocks, but are found associated principally with crystalline lime and magnesian rocks, such as calcite and pyroxene. The origin of these two classes will therefore be considered independently.

In addition to these sources of mica, it is a very common constituent of many fragmental rocks, ordinary quartz-sand, etc. Whenever a mica-bearing rock is eroded by water, particles of the mica which it contains are carried with it and deposited in beds somewhere in the course of the stream. Although mica is a heavy mineral (sp. gr. 2.6 to 3.2) its flaky nature causes it to be carried along or floated with an equal facility to lighter materials, such as sand, and when deposited with the latter in large quantities, the flakes falling naturally into a horizontal position, and the strata being afterwards consolidated, a schistose rock is formed, which easily splits by reason of the lack of cohesion between the mica plates.

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*Read by title. †Copyright, 1905, by George Wetmore Colles.

Such is doubtless the origin of most micaceous schists; but there are other rocks of a similar class and quality, which are to be classed rather as metamorphic, that is to say, rocks of a sedimentary or fragmental origin, but which, when deposited, contained no mica, and in which the mica has been developed by a process of slow crystallization under the continued application of heat. We pass thus gradually from the fragmental schists to gneiss, and go still further on the same lines from gneiss to granite, in which the bedding of the material has been entirely lost; and finally from granite to pegmatite, which latter may be described roughly as a kind of gigantic granite—a rock formed of the same materials but in very much larger crystals.*

Now, granite is a rock composed of three principal constituents, namely, mica, feldspar and quartz, and these minerals, as such, are not necessarily present in the rocks from which they have been formed. Their common occurrence, and more particularly that of mica, in rocks which have been altered by heat from rocks which did not contain them, is an evidence that, given the materials—alumina, potash, silica and water—and the necessary conditions, these materials will come together and crystallize out into mica of their own accord. That this is what happens, when a rock of sedimentary origin is altered to gneiss, is readily shown to be the case by the examination of a region of local metamorphism; that is, by examining the nature of the ground adjacent to a dike of igneous rock, for example, when what has been changed to gneiss close to the dike is, on following it back, found to pass gradually into sandstone, etc., the mica and other crystals making their appearance increasingly as we approach the dike.

Proceeding a step further from gneiss to granite, we have rock which results from a still further heating of the gneiss to at least a plastic condition, in which the materials have so rearranged themselves that the bedding is completely lost. The heat has been sufficiently continued and evenly maintained to permit the materials to group themselves into larger crystals.

*There are several differences between granite and pegmatite besides the mere size of the crystals, that point to a difference in *kind* as well as one of degree. One of these is the different character of the mica crystals.

It is a well-understood principle that the size of the crystals formed increases with the slowness of the action, and this principle is clearly illustrated throughout the igneous rocks, and assists us in explaining the manner of their formation. The same rock, for instance, in a volcanic vent, which will on the surface form a close-grained, amorphous or aphanitic lava, will be found to pass downwardly into a more crystalline form until we reach the condition of granite.

The pegmatic dikes in which the commercial mica occurs are, as before stated, composed of the same three body-minerals as in granite; but the crystals are often enormous, weighing several thousand pounds. The mica in these dikes is always in the form of more or less perfect crystals, called by miners blocks or "books." The feldspar is also more or less perfectly crystallized, but much of it is massive, and the bulk of the quartz is also massive. It is deserving of note, further, that while quartz veins* are of common occurrence, and while dikes of feldspar and quartz occur together without the mica—in fact about as frequently as with it—the mica itself, which constitutes the least bulk of the vein, is never found without both the feldspar and quartz.

It is also important to note in this place that the mica crystals as taken from the dike, are of rough, opaque and irregular exterior, and have rounded ends and angles. The outermost plates, and the edges of all the plates, are valueless, and have obviously either (1) suffered alteration from their original form, or (2) never quite reached the constitution of mica, strictly speaking.

With these preliminary considerations we are in position to consider, first the age of the dikes, and afterward the origin of the mica.

Age and Origin of the Pegmatite Dikes.

The mica-bearing dikes in New Hampshire, North Carolina, South Dakota and India, and probably in all other places where

*The net-work of coarse and fine quartz *veins* which commonly traverse the dikes and country rocks are merely an aqueous filling of cracks formed by the folding and faulting of the rocks, and must not be confounded with *dikes* of igneous origin.

mica has been mined, occur in rocks of the Archæan age, the first age known to geological history. The rocks of this age are not, however, either wholly or mainly igneous, but, like those of subsequent ages, are principally bedded or sedimentary rocks, which were once deposited at the bottom of a body of water. All, or nearly all, the rocks of the Archæan series, so far as known, have undergone metamorphic action, and become more or less crystallized. Into and through these rocks, which themselves contain mica in large quantities, but in minute scales, have been injected the dikes in question and take the form of sheets more or less continuous and irregular, cutting across or between the strata which they intersect. Now, it does not follow, because these are found in Archæan rocks, that they have been formed in Archæan time, as it is clear that, if no reasons to the contrary exist, they might have been formed at any subsequent epoch; but I believe that such reasons do exist, and that they show quite clearly that these dikes were formed shortly after the formation of the rocks themselves, at least in the case of the North Carolina series, to which the following remarks have application more particularly, although I believe in a general way they will apply to other regions where mica dikes are found.

These dikes, generally speaking, follow the strike and dip of the country rock; that is to say, are interposed rather between the layers than across them, though frequently breaking from one to another, besides branching out and becoming divided, and being of very irregular width. A single outcrop may extend several hundred feet on the surface of the ground, and may be as much as 50 to 100 feet in width (still wider ones have been found), or may have any dimensions less than these. The outcrop being "nipped" at any point (that is, tapering down to nothing), may begin again a little further on or at one side of the point of nipping. (See Fig. 20.) The distribution of the mica in the vein is not uniform, nor is it entirely irregular. It has a tendency to gather into bunches, or in strings of crystals. It may be found ranged along either or both walls of the dike, or bunched in the recesses thereof, or in branches and pockets of the dike, or again, packed in bunches in the center at intervals. Fig. 17 illustrates some of these peculiarities.

Fig. 17. Section of Point Pizzle (Cloudland) mine. *a*, dike; *b*, mica. (After Kerr.)

The influence of the wall rock on the material of the enclosed dike is often distinctly noticeable. Mica-bearing dikes predominate especially where they interpenetrate schists and micaceous gneisses; but not necessarily so, as good mica-bearing dikes also penetrate strata containing little mica. In India, however, this peculiarity seems to be very strongly brought out, and so much so that one writer on the subject assumes it as a proof of the aqueous rather than the igneous origin of the dikes.* The boundaries of the dikes are usually well defined and in close contact with the wall-rock, though a clay selvage has been observed at the juncture. This is undoubtedly formed by the decomposition of the dike-material through the action of water in the usual manner of feldspar. Fragments of wall rock are occasionally found in the dike, and Figure 18 is an example of a horse of wall rock running parallel to the dike, the only example known in North Carolina of this structure.

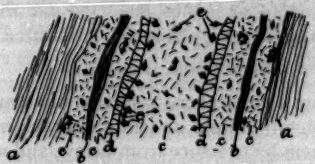

Fig. 18. Section in Silvers Mine (after Kerr). *a*, country rock; *b*, horse of same; *c*, dike material; *d*, quartz vein; *e*, mica.

In considering the origin of these dikes it seems to have been generally assumed that the dike-material was projected upwards while they lay in their present position. I cannot see any reason for adopting this view, while, on the contrary, there appear to me to be strong reasons for believing them to have been formed while the rocks were horizontally bedded. Moreover, with a few possible exceptions, there is nothing to show

*A, Mervyn Smith in "Mica Mining in Bengal, India." Trans. Inst. Min. and Met., Vol. vii, p. 170. This theory is referred to later. (See discussion on p. 282 *et seq.*

that the fissures, in which they lie, were ducts which led the material in a stream from some heated source below to the surface; but, on the contrary, they are distinctly of a *laccolithic* character; in other words, they were the mere filling of cracks which extended laterally from the source of molten material, probably ramifying from this source and ending in a *cul de sac*.

Figures 19 and 20 represent graphically the general manner in which the dikes may be supposed to have been formed.

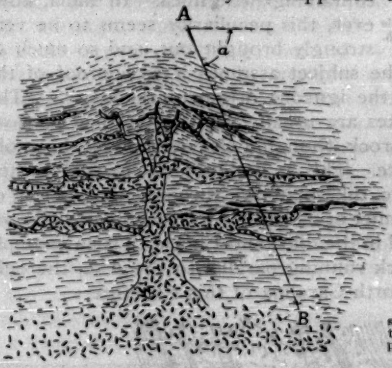

Fig. 19. Hypothetical section of laccolith of mica dikes.

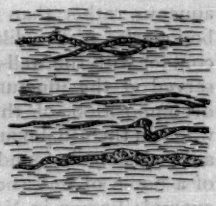

Fig. 20. Surface outcrop when strata of Fig. 19 have been tilted through angle a and denuded to plane A-B.

Figure 19 shows a vertical cross-section of a part of the bedded rocks and a column of fluid or semi-fluid rock-material injected upward into them by pressure from below, and naturally raising the strata above it. The rocks are supposed to be deeply buried under overlying strata, and the heat to increase downwardly until at their lower portion they become sufficiently fluid to be forced upwardly in the manner indicated, raising the overlying rocks. For the force to accomplish such an injection, we would only need to look as far as the difference in specific gravity between the solid and fused material, and the expansion of the water contained in the latter—I will not say *steam*, as is done by some writers, for it is clear that steam could hardly—at any rate did not—exist under this pressure and the comparatively low temperature which must be assumed. Whether the fissures were made by the pressure of the material which filled them or by some other agency, or by both acting to-

gether, is a question which need not here be answered. After the material filled the fissures an excessively slow cooling rate is demanded by the condition of the dikes, as we find them, by reason of the immense size of the crystals. Supposing, then, dikes to have been thus formed and cooled, and subsequently the rocks to have been tilted through an angle *a*, Fig. 19, and erosion taken place until the surface of the ground lies on the plane AB, the appearance of said surface would then be as shown in Fig. 20, which represents the dikes as we actually find them.

The reasons for the conclusions above adopted are as follows:

(1) The country rock shows a regional and not merely local metamorphism, as it would if it had been near the surface when the dikes were intruded, and such metamorphism were caused by the heat of the dike-material itself. In other words, the metamorphism of the rocks is comparatively uniform throughout the entire area under consideration. Such metamorphism implies that the rocks must have been buried very deeply in the earth, at least several miles below the surface. Now, that there has been an enormous denudation of the Archæan rocks,—greater, perhaps, than that of any subsequent series,—is clear when we consider that the rocks of all subsequent formations have been made from them. We must suppose, then, that the existing rocks were formerly overlaid by a thickness of several miles of the same system, and it is very improbable that much folding could have taken place before these subsequent rocks were laid down, or yet while they were very deeply buried, because we know that much folding has taken place since then, which, of course, tends to tilt the rocks always more steeply and never to return them to their horizontal position. The same holds good even if the strata overlying them were of a later age, for example, the Silurian or Carboniferous.*

2. The material of the dikes had no outlet to the surface, as it would have had if the rocks had been tilted (because the pressure would have been exerted to split a passage open instead of to raise the rocks); because (a) we find no deposits of material which would indicate such outflow; (b) the vein would have been banded, which it is not, or crystallized normal to the

surface, indicating a cooling from the exterior inwardly, which it is not; and (c) because the continued or interrupted flow through the fissure would have prevented the formation of any large crystals. With a few possible exceptions, like that illustrated in Fig. 18, the dikes are of a simple structure, that is to say, show that like conditions existed throughout, and no bands nor orientation of the crystals (unless it be that of the mica crystals *inter se*) can be observed.

3. To permit the slow rate of cooling demanded by the large-sized crystals and the other conditions just specified, the country rock must have been raised to a temperature approximating, if not equal, to that of the fused material, thus constituting a mass perhaps several miles thick, which would require centuries to cool down to the condition of complete solidification. This of itself indicates horizontal strata for the reason above indicated, viz., that the metamorphism took place before the tilting of the strata.

The aqueous theory of these dikes deserves mention here as it has been seriously put forward by at least one writer. The reasons given for this theory are as follows: (1) "in many places the veins die out in depth and in length;" (2) "the vein matter partakes of the quality of the including rock,—quartz, feldspar, and mica predominating, as the lode traverses rocks containing these minerals in excess;" (3) "the crystallization of the vein matter varies within very short distances, not being at all homogeneous as one would expect in an igneous dike. In places the crystals of mica are two feet long, eighteen inches wide and nine

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*From a consideration of the positions of the strata, J. D. Dana concludes that "no upturning took place over the Appalachian Mountains southeast (sic) of New England until the Carboniferous Age was approaching, or had reached its end."

A like conclusion is reached by J. A. Holmes, who has shown that the pegmatite dikes intersect the Archæan of Arizona, where it is cut through by the Colorado River in the Grand Canyon, coming up to the base of the Algonkian (the series next following the Archæan), which overlies these rocks, and consequently that the dikes were formed before the Algonkian period. In this case, however, the tilting of the rocks must have taken place during the Archæan itself, and consequently the intrusion of the dikes at a period long preceding even that comparatively early epoch.

inches thick. Within a few hundred feet on either side of this spot the mica books are small and worthless."*

Not only are the reasons so given to support this theory quite inadequate and inconclusive, but the theory is open to other objections which appear to me quite insuperable. Apparently it is based on the assumption of open fissures formed in the rock, into which ground waters carrying dissolved constituents of the country rock have flowed and evaporated, thus leaving behind the dissolved matter as a crystalline residue. To answer first the three reasons supposed to support the theory: (1) The fact that the veins die out in depth and length does not necessarily imply this theory more than another, as we have seen. (2) The influence of the substances of the wall-rocks can be explained equally well on the igneous theory; in fact such influence is commonly felt in igneous dikes. It is frequent for the materials of intrusive and intruded rocks to become interchanged through metamorphism,—not, however, that this has been the case here. Such influence is readily explained, more particularly where the wall rock is a friable mica schist or the like, on the assumption that the fissure produced by the fissuring forces was not a clean one, but that much of the rock-material was pulverized and mingled with the vein-material and subsequently dissolved therein and recrystallized. Besides, supposing the vein material to be merely melted wall-material from further down, it would naturally have a similar constitution. (3) That the constitution of an igneous magma should be not strictly homogeneous, but should vary within distances of a few hundred feet, is really no stranger than that an aqueous solution should do the same thing.

The most obvious objection to the aqueous theory is, that it presupposes fissures or voids in the rock which could hardly have existed. Either (1) such fissures must be formed while the rocks are still horizontal, or (2) after the rocks had been tilted, in which case they must have extended from the surface downward.The first assumption, in view of the great weight of overlying rock, is obviously untenable. The second is almost if not quite equally as untenable, by reason of the lateral pressure on the earth's crust which would close the fissures. Such

*A. Mervyn Smith, *loc. cit.*

fissures are indeed formed in the course of mountain-making upheavals but they are of a temporary nature, and are quickly filled with debris from the surface, which could not fail to show in the vein. Besides, as we have seen, the dikes have, in many cases at least, been formed before the rocks were tilted. I consider this reason alone conclusive against the aqueous theory. Further, however, it may be said that (1) the constituents of such veins, if formed, would be banded and would show a crystallization normal to the surface, and this as we have seen really never happens; (2) the water would evaporate too quickly to produce large crystals; (3) the mica portion of the vein-constituents is insoluble in water, and in fact in any other liquid, at surface temperatures and pressures. To suppose them to have dissolved out of the rocks and recrystallized by the action of water, is no more reasonable than to suppose that the mica had been conveyed there bodily. This fact also appears to me conclusive against the aqueous theory. In fact, the crystallization of mica, in the present state of our knowledge, implies the presence of heat.

Origin of the Mica.

Having thus determined the age and manner of formation of the dikes, it remains to consider how the mica was formed and reached its present position. Three views have been proposed: (1) that the mica crystals were formed in the fused rock-mass before the latter was injected into the fissures to form dikes; (2) that the mica existed separately as such in the fused mass at the time of intrusion, having been formed further down; and (3) that the mica, quartz and feldspar all existed together in a homogeneous solution both before and after the intrusion of the dike material, and that the several materials crystallized out one after the other in the same manner, as for example, salt crystallizes out as a result of mixing soda and hydrochloric acid; the several materials being brought together by chemical attraction in either case. That the third theory, or rather a modification of it, is the only rational one of the three can, I think, be readily shown to be the case.

First, however, we must consider which of the three principal materials of the dike reached the solid condition first. Under conditions as we know them in the laboratory, the feld-

spar has about the lowest and quartz the highest melting point of the three, the mica occupying an intermediate though somewhat variable position; but under conditions of high pressure and temperature, and added to these the elements of water, these conditions may be widely different. That water must have been present is to be taken for granted, both because it is difficult to assume a high enough temperature to have produced the effects without it, and also because it is present in the mica; as well as from the fact that steam is always given off in volcanic action.

The mica and feldspar are in fact both crystallized in a massive quartz matrix. The mica plates have left their marks both on the feldspar and on the quartz. It is clear that the mica could not have crystallized after the other two had solidified around it, therefore it is tolerably clear that the mica crystallized first, or at least concomitantly with the feldspar. We may assume that the feldspar and quartz together formed a vehicle for the mica. The crystalline form of the feldspar would seem to indicate that it separated out from the magma after the mica, leaving the quartz behind to solidify last. If the quartz still contained water (which would have made it more soluble) this has been subsequently driven off.

If the mica had been carried up in solid crystals mixed with the magma, we should here find it (1) all arranged on the hanging wall, to which it would have floated as soon as the magma came to rest, supposing it to have been lighter than the latter; or (2) it would have sunk to the bottom and we should find it all on the foot-wall of the dike, had it been heavier than the magma. Furthermore, it is utterly impossible that small branches of the dike could have been found packed full of mica crystals; in short, this theory is obviously untenable.

That mica may have existed as such in solution in the magma may well be admitted, but the question as to whether it existed in any special combination apart from the other elements, is about as futile as a like question with regard to all chemical solution. Suffice it to say that the arrangement of the crystals does not admit of any general theory, which does not presuppose that all the elements of the dike were uniformly mixed and tolerably homogeneous at the time they entered the fissures in which they cooled. Formed as they were from rocks

containing the same materials, and, indeed, the same minerals only in different form, they could not have recrystallized in larger crystals had they not been dissolved and recombined.

It has been shown that wherever the materials of mica are present in such a mixture, even though it be not fully fluid, they tend to be drawn together and to crystallize out as mica. The fact that chemical affinity exists sufficient to segregate them, even in a substantially solid rock, is shown by common local metamorphism, and is rather strikingly illustrated by the parallel case of crystallization or recrystallization of hard steel under long-continued vibration. In this case it requires a jarring movement to bring the molecules together; in the case where they are held in a partially or wholly melted state, for a sufficient length of time, chemical attraction alone seems necessary. The force that will explain the building up of a large mica crystal by the drawing together to one point of the elements of such a solution, seems absolutely identical with that causing a crystallization of any chemical substance from solution, more particularly if it be assumed that as the solution cools the mica becomes more and more insoluble therein.

That, moreover, the mica did so crystallize is plainly indicated by its local position in the dike, from its having, as aforesaid, a tendency to cling to one wall or to the other, or to cling together in aggregates precisely as in the case of other crystallization from solution, and the same reasoning pursued will explain equally the separation of the feldspar and quartz in great masses instead of in small particles as in other rocks.

Much has been said and somewhat has been written on a possible rule for finding the mica, and although miners themselves pretend to have rules and principles for finding it, it is pretty safe to state that no such rule exists, and that aside from the principle of crystallization which is alluded to, mica crystallized at random on one wall or the other, according to where chance happened to start the process. It was stated above that the dike material in the fused form was substantially homogeneous, but of course this does not necessarily apply to very extensive areas, and from place to place it would naturally vary in its contents of mica materials, thus giving rise to barren spots in the dike, and in some cases to dikes which were altogether free from mica; but the causes and order of such events would be as

difficult to define or regulate by rule as the movements of old Mother Earth herself.

The question as to what causes the rough, scaly exterior of mica crystals is one of considerable interest, and no doubt having an important bearing on the question of origin, but one which, so far as I know, has never been discussed. That it is not a result of secondary alteration or at any rate of the action of air and water penetrating from the surface, is, I think, all but certain. It has been shown that ordinary watering processes have little effect on ordinary muscovite, and if weathering were the cause, the effect would be limitd to mica dikes which have been partially disintegrated by weathering, and not extend into the solid rock itself. Moreover, there is no indication in the incasing matrix of any such alteration. Perhaps it has been due to the fact that when the mica was formed there was insufficient water taken up by the exterior portions to form perfect mica. This, however, is merely a speculation. There is, so far as I know, no published chemical analysis of the scaly exterior in comparison with the interior of the mica-blocks, and until we have such analysis, it is impossible to reach any definite conclusion.

As previously noted, the action of water penetrating through the material of the dike produces an alteration in the feldspathic contents, dissolving out the alkalies and leaving behind a hydrated aluminum silicate in the form of clay, while the mica and quartz are left untouched.

Occasional Minerals.

The pegmatite dikes, both of North Carolina and elsewhere, are noted for the number and variety of unusual minerals which they contain as accessories. A list of those occurring in the North Carolina dikes as prepared by W. C. Kerr, and corrected by F. A. Genth, is as follows:*

*Notwithstanding the revision, it seems very doubtful if this list is complete. *Rutile* (titanium dioxide) is a common inclusion in micas. *Pyrite* is almost always found in granitic rocks, though I do not remember having seen it in the Carolina dikes. Common *emerald* occurs in some mica dikes, as that of Villeneuve, Quebec. Probably also *ultramarines*. *Cassiterite* (tinstone) probably occurs here, as it certainly does in the dikes in South Dakota and elsewhere. *Kaolinite* is, of course, often present as a derived product. Spodumene (hiddenite), corundum, cyanite, and topaz also are mentioned as occurring with mica in North Carolina.

Albite	Magnetite
Allanite	Menaccanite
Amazon stone(?)	Monazite
Fluorapatite	Muscovite
Autunite	Phosphuranylite
Beryl	Pyrochlore
Columbite	Rogersite
Fergusonite	Samarskite
Fluorite	Thulite
Glassy feldspar(?)	Tourmaline
Garnet	Uraninite
Gummite	Uranocher
Hatchettolite	Uranotil
Limonite	Yttrogummite(?)

Many of these minerals are ores of the rare earths and elements, like cerium, thorium and lanthanum, etc., used in incandescent lamp mantels; uranium, used in the manufacture of fluorescent glass; niobium, tantalum and other rare metals, including, perhaps, the now famous radium; semi-precious gems, like beryl and tourmaline. These have formed from time to time a certain inconsiderable addition to the earnings of some of the mines. The question as to their source and meaning is certainly an interesting one, to which, however, so far as I know, no answer has ever been attempted.

THE PYROXENIC MICAS.

Whatever may be the origin of the micas in pyroxenic rocks, it is certain that it is very different from that of the micas just discussed. The difference is not only one of chemical composition, but also of geologic structure and character.

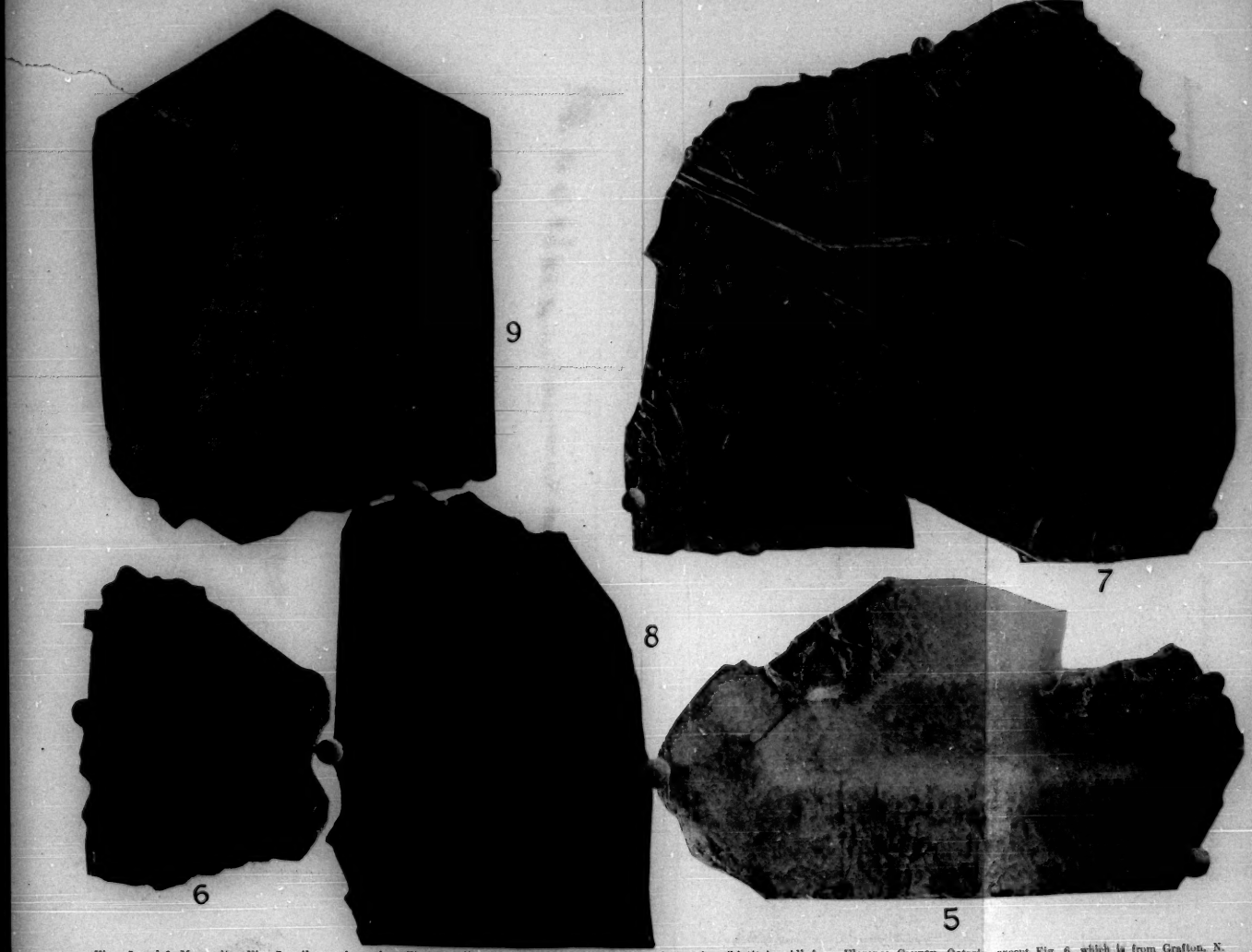
Magnesian micas are found associated with calcite (carbonate of lime) apatite (phosphate of lime), pyroxene (silicate of iron and magnesia), and hornblende (ditto). Although found in various parts of the earth's surface, they are unique in being known to occur in workable commercial deposits apparently only in the Laurentian of Canada.

The mode of occurrence of the Canadian mica deposits points to a more complicated mode of origin than that above assigned to the pegmatite likes. The magnesian micas do not

occur in normal pegmatite, although dikes of this material containing white mica are found in occasional deposits in their immediate neighborhood. The deposits of the magnesian micas and their associated minerals appear to be more in the nature of veins deposited through the principal agency of water, aided by some degree of heat. The country-rock consists principally of gneisses and metamorphosed and crystalline limestones. We find these country-rocks largely intersected by the veins of the associated mica-minerals, principally calcite and pyroxene, and these, as in the case of the pegmatite dikes, largely follow planes of the strata, but also cut across them both horizontally and vertically. The contacts between the vein material and the gneiss is often indefinite, indicating a widely extended impregnation of the latter by the former. These vein- or instrusive masses appear to be true fissure veins in many respects, indicating that the filling material was not under pressure. (1) The veins are frequently banded, and successive fillings alternating as pyroxene, calcite, etc., may be indicated. (2) The apatite and mica deposits are found in irregular pockets in the pyroxene, and the segregation of mica in shoots is common. (3) Void spaces forming chimneys and druses containing free crystals are of common occurrence. These could hardly occur under conditions of external pressure unless we suppose the presence of large quantities of gas or vapor. The presence of hot gases, moreover, is indicated in some places by the burnt condition of the chimneys. The veins do not die out in length or in depth, but they extend as far down as mining has yet been carried, amounting to from 300 to 400 feet in Quebec.

The most important geological feature to note about these magnesian mica veins is that the mica occurs nearly always on or near the contact surface between the pyroxene and one of the other rocks, especially calcite or gneiss. Dr. R. W. Ells, of the Canadian Geological Survey, has classified these deposits into three principal heads:* (1) Deposits between the pyroxene dike and gneissic country-rock; (2) in pyroxene near the

*"Mica Deposits of Canada," by R. W. Ells, Bulletin C. G. S., 1904. A fourth class is given, defined as dikes of pyroxene cut by both calcite and pegmatite, but this variety does not seem to be either frequent or well defined, and is admitted by the author himself to be a form of class 2, hence it is omitted above.



Figs. 5 and 6, Muscovite; Fig. 7, milgy amber mica; Fig. 8, yellow-brown amber mica; Fig. 9, black mica (biotite). All from Florence County, Ontario, except Fig. 6, which is from Grafton, N. H. Figs. 7 and 8 are both from the Lacey mine. Note darker color of Fig. 6 as compared with Fig. 5, due to inferior transparency of New Hampshire product. Fig. 5 is spotty, due to green infiltrations between the leaves.

contact of cross dikes of diorite or pegmatite (the mica of this class is pockety); (3) in pyroxene on and near a fissure plane. Though apparently inseparable from pyroxene to any great distance, the matrix of the crystals is often actually one of calcite of apatite, which is interpolated between the pyroxene and the country rock. The calcite and apatite do not always occur, as the pyroxene does, but the best mica appears to be usually found in the deposits containing these minerals—best both in quality and size.

From their nature, deposits of this class are very much more concentrated than in the case of the granitic micas. Instead of concentarted than in the case of the granitic micas. Instead of occurring in isolated crystals, it occurs in densely packed crystalline masses, which form a vein in themselves without much

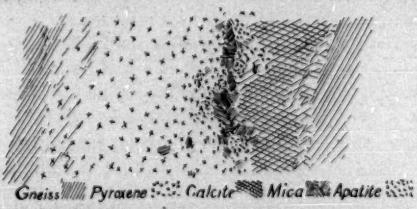


Fig. 21. Ideal section of Magnesian mica vein.

access of other material. These crystals are as a rule of small diameter and of very great length, but plates of immense size are common in some of the mines. These plates, like those of white mica, are frequently bent, twisted and flawed, but the reason appears to lie in the crowding of the crystals among themselves rather than in the bending and folding of the strata in which they occur. The crystals lie with their axes in all directions, haphazard, and without any observable arrangement; and the sides of the crystals, that is, the edges of the plates, are for the most part not rough and ragged as in the case of the granitic micas, but are smooth, clean and polished. As might be expected from the solid interpacking of the material, voids in the interspace are of frequent occurrence. (See Fig. 21.)

It is obvious that the contactual nature of the micas and their immediate association with pyroxene form the most important indices to the origin of the mica. Whether segregated from

the elements of pyroxene alone, or whether formed by a new chemical combination from these jointly with those of some other rock, it seems impossible to say with certainty, because an explanation that would do for one deposit would fail for another. The most probable theory seems to be that the mica is a surface crystallization upon the pyroxene and from materials contained in it while the latter was still in a plastic condition. That it could have been formed after the rocks solidified is clearly impossible.

Age of the Canadian Deposits.

The Laurentian hills, in which these deposits occur, belong not only to the Archæan age, but to the oldest recognized period of that age. It is generally held among geologists, following the original theory of J. D. Dana, that this portion of the earth's surface has been out of water nearly all the time since the strata were first raised, which raising is supposed to have taken place before the beginning of the Cambrian epoch. There are doubtless indications that this may have been the case, and also it may not be too much to state that proofs are lacking.*

*In drawing his "Archæan Map of North America," Prof. Dana simply drew in the Archæan areas of the present day as land, and everything else as water, stating that these areas formed the nucleus of the continent; which forms a part of the argument for the semi-religious thesis on which his views of geology were based; and subsequently geologists seem to have simply adopted Dana's views. In other words, the continent began with the present Archæan areas and continued in a general way evolving from this as a base to its present extent. As all subsequent formations have been derived from the Archæan this necessarily supposes that the material which went to form all the other deposits of the continent, from the Cambrain to the Quaternary, were at one time heaped up on the present Archæan areas. So stated, the theory appears in its true light as nothing less than ridiculous. Besides, to suppose that the present Archæan areas constituted the first land is nothing less than impossible, for these rocks are stratified, and consequently, in the nature of fragmental rocks, were derived from *other* land, either by means of rivers or ocean currents, which other land must have existed before these Archæan areas were formed. Inasmuch, then, as other land than the present Archæan constituted the first land of the continent, and the nucleus has been changed at least once, we may as well admit that it has been changed a hundred times. We do not know what is under the earth more than a few thousand feet, and if, for example, some point in Arizona were subjected to a continuous raising and denudation for a sufficiently long time, washing away one formation after another until the Archæan was reached, it would offer a very similar condition to that of the Laurentian Hills, and no doubt ancient beaches, etc., would be found which would bear up the theory that this point formed the beginning or nucleus of the continent.

But the present area was, at all events, at one time covered with many thousand feet of superposed strata of *some* age. The question is, (1) were the mica deposits, etc., made during the Archæan age and prior to the general metamorphism of the rocks in which they occur; or (2) were they deposited in subsequent ages when overlain by rocks of later periods, and then metamorphized—being perhaps derived by infiltration from aqueous solutions bearing material from these latter rocks; or (3) have they been formed by aqueous deposits since the metamorphism of the rocks, and never undergone any metamorphic action? These questions are much more difficult to answer than the questions as to the origin of the granitic micas, and, in fact, a definite answer cannot yet be given. Certain considerations, however, point to the last of these three views as the most probable. The manner in which the veins intersect the strata of gneiss and each other, and the presence of chimneys and voids, appear to indicate with tolerable clearness that the strata had been metamorphized and upturned before the veins were formed. For the same reasons the veins were probably formed near the surface, and extended perhaps but a short distance (several thousand feet) below it. Expanding gases may have opened the rock-fissures and a heated magnesian-aqueous magma followed to fill them. This agrees tolerably well with the theory of Dr. R. W. Ells, of the Canadian Geological Survey, that the material was derived from igneous sources as submarine injections. This must have been prior to the laying down of the Cambrian and Silurian, which immediately overlie the Laurentian series and limit the exploitable area; for no mica dikes are found in any of these.

Relation of Mica Deposits to Archæan Age.

Existing *commercial* mica formations appear to be exclusively confined to the Archæan rocks—though there may be exceptions. We are naturally inclined to ask, Was there some peculiar geological condition acting in the Archæan, which produced these rocks, and which does not now exist? I believe there is no need for such a hypothesis. We know that mica in small crystals occurs in crystalline rocks of all ages, and that such crystals are produced naturally in these rocks wherever the materials

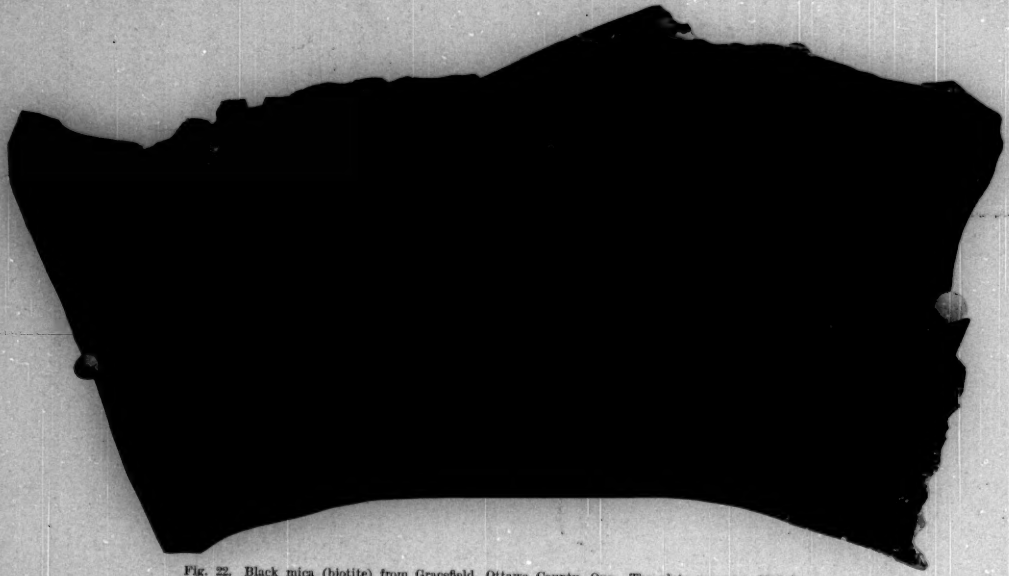


Fig. 22. Black mica (biotite) from Gracefield, Ottawa County, Que. The plate measures 20x9 in.

for its formation are at hand, and the heat is continuously maintained. We know that the Archæan rocks differ from all later rocks in being universally metamorphized; but this is obviously explainable in the same manner as the greater extent of metamorphism among the primary or secondary than among the tertiary rocks; namely, that they have been more deeply buried than others; and not by invoking an extraordinary terperature on the earth's surface in the earlier time.* As previously explained, the pegmatite dikes imply the burial of the rocks in which they occur beneath several, perhaps many miles of overlying strata, a condition which could have been attained only by the Archæan rocks; or, if attained by others which exist today beneath the earth's surface, the time has been insufficient to raise them and denude them sufficiently to expose the deposits. This does not, indeed, explain the Laurentian micas, unless we assume them also to have been formed at a great distance from the surface; but it should be remembered that these are the only deposits of magnesian micas of importance that have as yet been commercially worked, and that little as to their day or manner of origin can be certainly predicated at the present time.

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*The fact should be emphasized here, that the Archæan age was an age of land and water, of building up and of laying down, in every way similar to the present so far as concerns any evidence to the contrary, and was emphatically *not* an "age of fire," as it is frequently thought of as being. I have heard Archæan rocks talked of, by persons who ought to know better, as "plutonic," meaning rocks which originated through cooling from a state of incandescence at the time that the globe first solidified from this state. The stratified condition of the rocks shows emphatically that this is not the case. If there was an "age of fire," no evidence of it can be obtained from the rocks themselves, and it must have preceded the Archæan Age by at least as long a time as has elapsed since its close.

Another common assumption is that the Archæan preceded the origin of life on this planet, and it has been called the "Azoic," or lifeless age—because the Archæan rocks contain no recognizable fossils. No assumption could be more gratuitous. It would be, of course, a bootless task to search for fossils in granite, calcite and pyroxene, but fortunately there is abundant evidence for the existence of life of a varied and comparatively complex character in the Archæan.

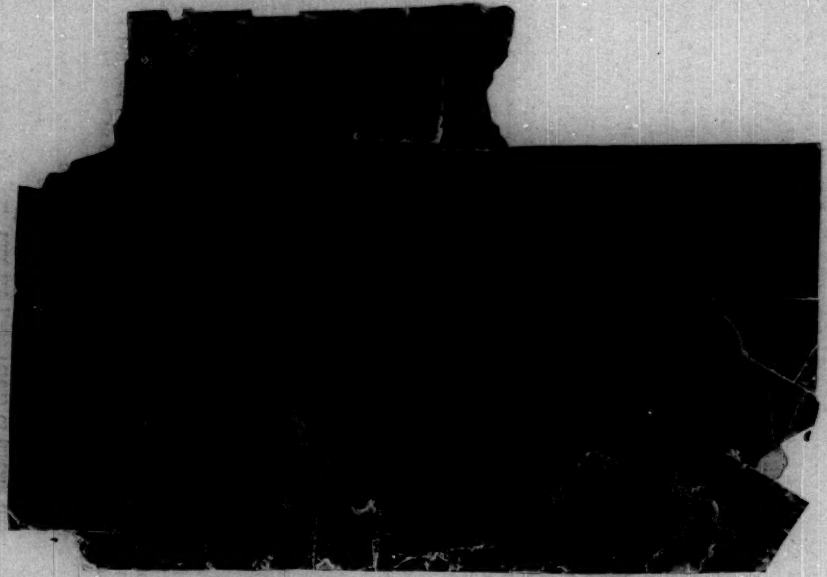

Fig. 23. Normal amber mica (mottled), from Lacey mine, Sydenham, Ontario. This plate measures 23x17 inches. The upper and lower edges are lines of natural ruling, hence the plate is but a fraction of the size of the entire crystal.

HEALING QUALITIES OF EGG MEMBRANE.

At a recent session of the Therapeutical Association of Paris, Doctor Amat lectured on the use of membrane of eggs in the treatment of wounds. He has observed for some time the good results of placing these membranes upon the surface of wounds, and reports two new cases, that of a young girl suffering from a burn on her foot, and a man, forty years old, with a large ulcer on his leg. Both wounds are in process of healing, and were covered with healthy granulations. The surgeon overspread them with six or eight pieces of the membrane of eggs, which was covered with tin foil and fastened with dry antiseptic bandages. After four days the bandages and tin foil were removed, and it was shown that the membrane of the egg had partly grown into the tissues and had caused the growing of a good skin. That the egg membrane had contributed much to the healing process was demonstrated in the further course of treatment. It seems, however, that the membrane does not always adhere. The process of cicatrization is not only hastened but the wound heals exceptionally well and leaves but few perceptible traces. As these membranes are procurable everywhere their use should attract more attention.—*Richard Guenther Consul-General, Frankfort, Germany, May 15, 1905.*

PREPARATION OF RAILWAY CROSS-TIES.

The *Revue Générale des Chemins de Fer* describes the preparation of cross-ties by the Compagnie de l'Ouest by means of the injection of creosote. Works for the purpose are established at Surdon in the department of Orme, about the center of the railway system. The yard occupies more than eight hectares. The ties, on arrival at the yard, are classified according to their comparative resistance to the penetration of creosote, and are piled up so as to dry by means of a free circulation of air. This requires from six months to a year, after which they are placed in hot-air driers for twenty-four hours and afterward in large hermetically sealed injection cylinders, heated by steam worms, under a pressure of two kilogrammes, which allows of maintaining a uniform temperature of 80 deg. C. for the creosote. A vacuum is produced in the cylinders, which are put in communication with the creosote vats. When filled with the liquid, an inside pressure of seven kilogrammes is caused by means of pumps for thirty-five or forty-five minutes. The annual production at Surdon is 297,000 cross-ties, and 200,000 posts, stakes and other pieces.—*Scientific American.*

THE DISPOSITION OF THE BOSTON FRANKLIN FUND.

The Board of Aldermen of Boston, Mass., has formally accepted the offer of Andrew Carnegie of an endowment fund of $400,000 to be used for the maintenance of a trade school to be established by the Benjamin Franklin Fund, which is the accumulation of a bequest by that eminent American made a century ago. The condition of Mr. Carnegie's gift is that the institution be patterned after the Cooper Union, New York.

Stated Meeting, held Thursday, April 18th, 1905.

The Sanitary Protection of Water Supplies.

By Kenneth Allen.

Chief Engineer Water Department Atlantic City, N. J.

[Unsanitary conditions may be detected by analysis of water, by inspection of watershed or by mortality statistics. Knowledge of the life history of the typhoid germ and registration of vital statistics are important. Presumptive tests for B. Coli valuable.

Corrective treatment may be applied by the individual but should be applied to the entire supply. It may consist in: 1. Prevention of pollution; 2. Adoption of a pure supply; 3. Purification of an inferior supply. Control by Boards of Health, with Federal control as a last resort, is suggested. In any case ample power and funds should be provided. In selecting method of securing pure water with limited resources do not strive for ideal results in some detail at expense of greater general benefit.—The Editor.]

It is with a feeling of diffidence that I approach the subject of sanitation with relation to water supplies in a city where it has been uppermost in the minds of the people for a generation, where most eminent advice has been given with regard to the betterment of its own supply and where, finally, monumental works to alleviate the intolerable conditions of the past are approaching completion. But it is one of those matters concerning which eternal vigilance is the price of safety, and, moreover, it is one in which a marked development is taking place; and these are perhaps sufficient reasons for speaking on this subject to you to-night.

It has been said that the three great evils to mankind in the past have been war, pestilence and famine. In spite of the increased efficiency of modern arms and the recent activity in the East this great evil is becoming less and less. This, as pointed out by Bloch, is partly on account of the fearful destructiveness of scientific warfare from an economic point of view, but perhaps more on account of the rapid development of the humanitarian instincts since the first of the last century.

Famine, too, is a thing of the past in all civilized countries on accunt of the ample facilities for transport of supplies and the transfer of news, due to the use of steam and electricity. And, compared with the Middle Ages, modern society may be said to be free from the horrors of pestilence. With ordinarily decent modes of living those terrible scourges the plague and typhus have become practically extinct; with the general practice of

vaccination smallpox is not to be feared as in the past; more recently the prophylactic properties of specific serums are reducing the mortality due to diphtheria and other diseases and by the extermination of the stegomyia fasciata and anopheles mosquitoes the spread of yellow fever and malaria in Cuba and Panama is being controlled.

But in spite of all this progress in the prevention of disease the mortality from typhoid fever remains about 45* for each 10,000 inhabitants in the United States, and 52.8 in the case of Philadelphia; while it has been recognized for some years that this disease is due to a specific bacterium, that it is usually conveyed by drinking water, and that it is what is termed a "preventable" disease.

Growth in our knowledge of the causes of disease and its prevention have kept pace with growth in general sanitation. At the beginning of the 19th century conditions and customs were tolerated in English towns that to us seem inconceivable, while the simplest means of avoiding infection were neglected in those cases where the direct relation of filth to disease was not evident.

The case of the Broad Street pump, in London, whose clear, sparkling water caused in 1854 the deaths of 616 persons, is well known, yet even to-day it is hard to convince many that the danger in polluted water is generally invisible. Nevertheless, especially during the past thirty years, the early years of bacteriology, appreciation of the relation between water supply, filth, infection and disease has made rapid advances, and there is a marked demand for purer and safer supplies. What I wish to point out is the fact that the present attitude regarding this subject, as that regarding electricity, corporations, transportation, organized charity and prison reform, *is essentially modern—so* modern that as yet there is need of much educational work and much effort to utilize the knowledge we already possess.

The problem confronting the sanitarian is two-fold: the *detection of unsanitary conditions* and *their remedy*. In the matter of public water supplies we wish to avoid in particular ingredi-

*Estimated at 46.27 by Dr. Osler in 1890, who also estimated a rate of 17.9 for England and Wales, 65.8 for Italy, 47 for Austria and 20.4 for Prussia.

ents prejudicial to health. Mineral-poisons are seldom found but living organisms or their products may be the vehicles by which most dangerous diseases are transmitted, and it is the detection of these that most concerns the sanitarian. And right here it will generally be necessary for him to call to his aid the expert services of the chemist, the bacteriologist and the biologist.

But a few years ago, when it was found that the potability of a water could not be affirmed by its appearance, it was supposed that a chemical analysis would completely reveal its character.

This is true in a general way only. Gross pollution is readily detected by analysis and water of high chemical purity is seldom to be feared; but we now know that, in the dissemination of disease, bacteria, which are not discoverable by the methods of the chemist, play an essential roll. And while a public water supply should be free from sediment, color, objectionable tastes or odors, excessive amounts of iron, lime, magnesia or constituents that are capable of dissolving lead or other service pipes or fittings, the infection of a water supply by pathogenic bacteria, as the most important phase of the question, is the one I shall dwell upon in particular detail.

THE DETECTION OF UNSANITARY CONDITIONS.

Unsanitary conditions regarding a water supply may be detected by an examination of the water itself, by making a sanitary inspection of the watershed, or it may be revealed by the health and mortality statistics of the community served—especially those due to intestinal disorders such as diarrhœa, typhoid fever and cholera. The first of these complaints is not often fatal and is generally readily controlled by ordinary care in diet; cholera, although a most fatal disease, does not often obtain a foothold in well-regulated communities; but typhoid is always with us. It is, then, to the suppression of this disease more than any other that particular effort should be directed, and we may do this confident of success now that the cause of the disease and many of its characteristics are known.

Typhoid fever is the result of the lodgment and development of the typhoid bacillus on the walls of the intestinal canal to which it is conveyed by our food or drink; and while cases and

sometimes epidemics have been caused by infected shell fish, milk and other food stuffs that have become contaminated—perhaps by flies or by careless handling—the use of impure water is the most common source of the disease. It behooves us, then, to learn how our water supplies may become infected, how to detect such infection, what remedies to apply and what precautions to take to guard against further infection.

Prof. Sedgwick has said* that the germs "of typhoid fever are so few that all search for them by competent observers is usually in vain * * * . In comparison with the whole number of bacteria, those of typhoid fever are probably as rare as planets are among the stars, while, unlike the planets, they have no marked features of size or motion which enables them to be readily distinguished."

Although it may be said that the typhoid bacillus "has been found but by two or three competent observers so far in typhoid-producing natural waters"† we have been made somewhat familiar with its characteristics by recent studies by bacteriologists of cultures derived from infected sewage or dejecta.

From the standpoint of the sanitarian it is most important to ascertain the longevity of the typhoid bacillus under different conditions, especially in water, and the following are results that have been found by several observers:

Frankland experimented on the life of the typhoid bacterium in the polluted surface water of the Thames, the soft, peaty water of Lock Katrine and hard water from a deep well with the following results:

	Days when last bacterium was observed.		
	Thames.	L. Katrine.	Deep well.
When placed in raw water.....	9	19	33
Water sterilized by steam.....	32	51	20
Filtered water	11	39	11

Mr. George W. Fuller has found that the "typhoid bacterium continues to live in the waters of the Merrimac river at Lawrence, in greatly diminished numbers, for a period of at least twenty-four days.‡

Another authority states that "in sterilized water typhoid

*Sources of typhoid fever in Pittsburgh—1898.

†Rep. John A. Amyot, M.D., San. Jour. Provincial Bd. Hlth., 1904.

‡International Public Health Congress—1893.

bacilli do not multiply, but perish in from one to three months. In water where there is much organic matter they may live longer, but the ordinary water bacteria seem to destroy them speedily."

Perhaps the most reliable data regarding the longevity of the typhoid bacillus have been obtained by Messrs. E. O. Jordon, H. L. Russell and F. R. Zeit in a series of elaborate experiments made at the request of the Sanitary District of Chicago about a year ago. These are of particular interest from the fact that natural conditions or environment, including change of water, were employed by enclosing the organisms in permeable sacs of parchment or celloidin and immersing these at various points in Lake Michigan, the Chicago River, the Drainage Canal and the Illinois River. The soluble products of organisms existing in these waters were therefore brought into contact with the typhoid bacilli by osmosis while the bacilli themselves could not escape.*

These gentlemen found that under these conditions "the vast majority of typhoid bacilli * * * perished within three or four days," although "it is theoretically possible that specially resistant cells may occur which are able to withstand for a longer period the hostile influences evidently present in the water." And they further conclude:

1st. "That typhoid bacilli die out more readily in unsterilized water than in the same water sterilized by heat;" and

2d. "That when typhoid bacilli are introduced into unsterilized water containing little organic matter, their longevity is more prolonged than in water charged with considerable organic matter."

As to their survival during low temperatures, Professor Wm. T. Sedgwick says:†

"The latest and most trustworthy investigations on this subject do not support the idea that any considerable number of cases, even in a large city using a comparatively impure ice supply, can be traced to this source, and it is a remarkable and important fact that no epidemic or other excess of typhoid has ever yet been undisputably traced to infected ice.'"

*Some doubt as to this last point has been recently raised by the results of experiments by W. R. Copeland at Columbus, Ohio. K. A.

†"Source of Typhoid Fever in Pittsburgh."—1898.

It appears, however, that this bacterium persists longer in cold weather than in summer.

As a rule deep-seated soils are sretile; but sewage bacteria have been found at considerable depths when forced through a porous soil by continuous dosing on the surface.

Mr. Fuller states that the typhoid bacillus has been found alive in the soil after five and a-half months, and that it has been found at a depth of nine and a-half feet.

Dr. Martin, of England, finds that "'in certain virgin soils * * * the typhoid bacillus does not grow nor live under any condition of the soil, sterilized or unsterilized," but that "in cultivated soils, *i. e.* those containing organic matter, that have been sterilized, the bacillus lives for a prolonged period and spreads through the soil. If, however, the bacillus be added to a cultivated soil, sterilization of which has been omitted, the micro-organism cannot be obtained from such soil after twelve days or so."

Mr. George C. Whipple found, in examination of the sands of Long Island containing from 136,130 to 200,000 bacteria per c.c. at the surface, that at a depth of two feet there were but from 2,850 to 35,870; at a depth of 4 feet from 280 to 2,240, and at a depth of 7 feet from 0 to 170. "These results," he says, "indicate that below a depth of five feet the sand never contains more than a very small number of bacteria."

The longevity of this organism has a most important bearing on the transmission of typhoid by flowing water and has brought out elaborate arguments in testimony before the U. S. Supreme Court concerning the effect of Chicago's Drainage Canal on the water supply of St. Louis. Between the tendency of this organism to die out and the effect of dilution by the comparatively pure water of Lake Michigan it is argued that the waters of the lower Illinois and of the Mississippi at St. Louis are actually rendered safer and more pure than before.*

In fact, from a large number of analyses of the waters of the Illinois and Mississippi Rivers extending over the years 1897-1902, Prof. A. W. Palmer finds that "'although the quan-

*Mr. John W. Alvord, assuming an average of 100,000 persons for every twenty deaths on the various drainage areas determines "effective populations contributing pollution" of 3,750,000 at Chicago, about 2,000,000 at Peoria after flowing five days and but 100,000 after flowing fourteen days.

tities or organic matters in the sewage now discharged into the Desplaines and Illinois Rivers are 30 per cent. greater than before, the proportions of organic matters contained in the waters discharged by the Illinois River into the Mississippi are very considerably smaller than they were prior to 1900; and that the decrease of the proportions is not a mere dilution, is shown by the fact that the actual quantities of organic matters discharged are less than they were formerly."*

According to Messrs. Zeit and Fütters:†

The Seine at 70 kilometers below Paris, the Oder 32 kilometers below Breslau, the Isar 33 kilometers below Munich and the Limmat 14 kilometers below Zurich, are each as pure as before entering these respective towns.

These gentlemen, after much experimental study, arrived at the following conclusions, the first of which, however, should be accepted with caution as not entirely in accord with the consensus of opinion among sanitarians, viz.:

"A seriously polluted water becomes pure again after flowing a certain distance. Pathogenic bacteria and sewage bacteria decrease as organic matter decreases. At the same time water bacteria increase. The presence of saprophytes hastens the removal of organic matter and the death of pathogenic bacteria.

"The quantitative bacteriological examination must give way to the qualitative, because a few infectious bacteria per c.c. constitute a more severe water pollution than a very great number of water bacteria."

According to Mr. Whipple, "The soil is the great repository of bacterial life, and every rainfall that washes the surface of the ground carries countless millions of bacteria into the streams. Hence, after every rain the number of bacteria in the water supply increases. The heavier the rainfall the larger in general will be the number of bacteria found. * * * Speaking generally, * * the numbers of bacteria in the Croton water measures the amount of surface wash into the stream, and hence the chance of infection."‡

Contrary to public opinion it will be seen that, so far as transmission of disease goes, the infection of a small rapidly-flowing

*Chemical Survey of the Waters of Illinois—1903.

†Sanitary Investig. of Ill. River. Ill. St. Bd. of Hlth., 1901.

‡Rep. Com. on Add. Water Supply for the City of New York, p. 378.

stream is more to be feared than that of a sluggish stream or reservoir. The great lakes receive untold polluting material, and yet furnish a wholesome water supply, except in the vicinity of towns. According to Whipple, "A water ten days after infection is perhaps one-sixth as likely to cause disease as that water one day after infection, while in one month it is perhaps one-fiftieth as great. The value of large storage reservoirs is thus evident."*

Moreover, as infecting material received by a small stream will be conveyed in a concentrated form, these require more vigilant inspection than large ones—other things being equal. The characteristics of large rivers are more permanent. In recent investigations into the filtration problem at New Orleans it was found that the Mississippi River at this point, although receiving the drainage from the vast population on its drainage area, was comparatively free from bacteria and organic pollution.

It is partly on account of the use of small streams, although more particularly from the careless location of wells and the lack of supervision over water supplies and drainage, that typhoid is often spoken of as a *rural* disease. And from its prevalence in the country on areas utilized, perhaps, for the collection of public water supplies, the need of efficient sanitary inspection of such areas is evident.

Conceding that typhoid may be derived from polluted oysters, dust containing the typhoid germ or polluted milk; that cases may be imported from other cities or induced by careless nursing, it remains a fact that the typhoid mortality of a town is perhaps the best single test of the quality of its water supply.

Why is it that Philadelphia, Pittsburgh, Allegheny, Troy, Albany and Washington have had typhoid rates in the past of from 65 to 110 per 100,000? And why is it that Boston, New York, St. Louis, Buffalo, Jersey City and Providence have had but 19 to 29 deaths per 100,000? while in Berlin, Hamburg, Munich, Dresden, Hanover, Leipsic and Cologne the mortality is but from 4.6 to 9 per 100,000? Unquestionably because the first-named cities have had polluted water supplies, the second set supplies from good natural streams or lakes,

*Report on Quality of the Present Water Supplies of New York City—1904.

while the third set have supplies raised above suspicion. This opinion is confirmed when we come to study the epidemics of typhoid such as those at Plymouth and Butler in this State, Lowell and Lawrence in Massachusetts, Ithaca, N. Y., and many others, where there is abundant evidence of the contamination of the water supply by typhoid dejecta. In the first of these 1104 cases and 114 deaths were directly traced to one typhoid patient, although the water had first passed through three storage reservoirs having a combined capacity of 5,000,000 gallons. Further confirmation is found in the relative typhoid mortality before and after the purification of the supply as has just been illustrated in your own city, Lawrence, Albany and Chicago. In Berlin, before 1883, the mortality from this cause was 1 in 9,000. After the introduction of filtration works the rate was reduced so that since 1893 it has been but 1 in 10,000, or half as many as in New York. In 1876 it was 1 in 10,850 in Philadelphia, while now it is but 1 in 1890.

Yet another evidence that water is the chief cause of typhoid is mentioned by Dr. A. Seibert,* who attributes its prevalence in New York during warm weather—as has also been observed in the Prussian army—to the fact that more water is drunk at this time of the year, and that bacterial life is then more active and abundant.†

Turning now to the lives sacrificed annually by typhoid, these probably aggregate in the United States about 50,000; in New York 425; in Chicago (previous to 1900) 900; in Philadelphia (1890-1900) 600, while the loss in dollars and cents to the State of Connecticut alone in 1902 has been estimated at twenty-five million dollars. Mr. John W. Hill, of your filtration bureau, has estimated the annual loss from typhoid in the United States at $278,000,000.‡

It would seem only necessary to bring the intelligent business men of the community to a realization of such losses and the possibility of their control to ensure every safeguard over our water supplies.

It is most important that accurate statistics be kept of all

*New York Medical Journal.

†The N. Y. Sun states that of 6,000 cases per annum in New York, half occur in the fall and one-fourth in the summer.

‡The Relation of Water to Typhoid Fever, 1898.

typhoid cases as well as deaths, for it is by noting an abnormal increase in these that we can best receive warning of an epidemic, and by properly interpreting a comparison with corresponding figures for other towns, that we may be in possession of one of the most valuable factors required in forming an estimate of the potability of a given supply. Dr. A. C. Abbott, Chief of the Philadelphia Bureau of Health, has said that "of the data relating to suspicious water supplies, those which are most trustworthy and constant in their indications are the regularly recorded vital statistics of the community using such water."

For this reason it is most unfortunate that the registration of vital statistics is not compulsory in this State although there are indications that this may be remedied before long.

The pollution of a water supply may be indicated by the examination of a sample of the water. Turbidity, color, odor and taste are sometimes indicative of its quality, but a chemical analysis is required to give quantitative results and to enable the expert to make a good guess as to the cause of pollution, if such be found, and whether it is recent or of long standing.*

Zeit and Fütterer state that "To establish the normal impurity of a river, the water level should be falling and no rains to increase the normal pollution * * * * Bacterial purification of a river can be judged by the gradual disappearance of pathogenic and sewage bacteria with falling water level.†

As a water used for drinking purposes should be judged when at its worst, however, samples should be taken both during a drought, or at least during a low stage of the stream, when impurities will be in a state of greater concentration, and immediately after a hard rain, when impurities will have been washed into the stream from the surface of the ground.

Pollution is indicated by the amount of nitrogenous matter

*Mr. X. H. Goodnough states among numerous similar examples, (Report of Commission on Charles River Dam, 1903) "The waters of the Connecticut River * * * do not show any evidence to the senses of the pollution they receive after the sewage has entered the river at Holyoke, Chicopee, Springfield or West Springfield, excepting floating matters, chiefly from manufacturing wastes."

†Report to Ill. St. Bd. of Hlth. on Examinations of the Waters of the Ill. River, 1901.

in a sample of water, by the decomposable organic matter as indicated by the oxygen into which it will enter into combination and by the colorine above that found normally in the natural unpolluted streams of the neighborhood.*

None of these constituents is necessarily harmful, being rather *indicative* of pollution—past or present, vegetable or animal. As to the interpretation of the analysis, this should be done with great care and only considered final after confirmation by an expert. Even then the chemist may fail to discover the direct cause of disease—pathogenic bacteria, and it is necessary to turn to the bacteriologist for aid.

Bacteria are present in surface waters in countless numbers. The limit for a good drinking water has been placed at from 100 to 300 per c.c. Those ordinarily found are called saphrophytes, and are generally considered harmless, while others—pathogenic bacteria—are known to cause specific disease.**

Sewage may contain as many as thirty-five million per c.c.; rivers vary greatly, but may contain from several hundred to as many thousand; ordinary wells four or five hundred, while the waters of Lake Superior contain but from twenty to thirty per c.c. and artesian wells none.†

Now, although the dejecta of a typhoid patient may contain

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*Rough limits of these several constituents for a drinking water may be taken as the following in parts per million:

Chlorine	10	above normal
Albuminoid Ammonia	0.02	
Nitrates	0.05	
Nitrites	None	
Oxygen consumed	4	

**Bacteria are also classed as ærobic (normally requiring oxygen) and anærobic and as liquefying (those which liquefy solids) and non-liquefying bacteria. Of 440 varieties known, 196 are liquefying bacteria. In sewage there have been found, per cubic inch (cc?):

5 million anærobic liquefying bacteria
12 " " non-liquefying bacteria
8 " ærobic liquefying bacteria
77 " " non-liquefying bacteria

or about 100 million in all.

†As to their size it has been estimated that it would take about 53,000 to weigh a grain. The typhoid bacillus, which was discovered by both Eberth and Koch but 25 years ago, is about $\frac{1}{20000}$ inch in thickness and several times as long.

as many as 2,000,000,000 typhoid bacilli per gram* it has been pointed out that by dispersion or death these are not readily found in even a grossly polluted water. Fortunately a more persistent bacterium universally found in the intestines of man and animals, known as the Bacillus Coli, affords an excellent means by which we may infer pollution from animal sources and hence danger as a conveyor of disease germs. Presumptive tests are therefore usually made for this bacterium. So universally is this found in surface waters, however, that perfectly good supplies may give positive tests with 10 c.c.†

Mr. Whipple suggests the following provisional scale by which the character of surface water may be judged according to the B. Coli it contains:

If found in	100	c.c.	the	water	may	be	assumed as safe
" "	10	c.c.	"	"	"	"	reasonably safe
" "	1	c.c.	"	"	"	"	questionable
" "	0.1	c.c.	"	"	"	"	probably unsafe.
" "	0.01	c.c.	"	"	"	"	unsafe

With regard to well waters the presence of this organism "is an almost infallible indication of the presence of contamination with surface water.‡

The identification of other forms of bacteria in the examination of water supplies is as a rule deemed superfluous and not attempted in this country, although it is recognized of much importance in studies of sewage purification.

Of several characteristic sewage bacteria it may be said, however, that *strepococci* survive in the soil but a short time; *B. Coli* disappear as a rule rapidly, but certain "strains" may survive for weeks or months, while *B. enteriditis sporogenes* may persist for long periods. The first two, therefore, indicate recent pollution—the latter, if alone, pollution in the past.**

In general, it may be said that chemical and bacterial examinations are mutually supporting, that the former are of greatest value in detecting conditions liable to cause offense to the senses, while bacterial examinations are of greatest value in determining the safety of a drinking water.

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*Hazen, Filtration of Public Water Supplies, 1898.

†George C. Whipple. "Quality of the Present supply of New York City."—1904.

‡Technology Quarterly, March, 1903.

**See report of Royal Com. on Sewage Disposal, 1905.

Examination of water supplies is regularly made now by most cities of importance. Chemical analyses are made by Baltimore, Brooklyn, Buffalo, Chicago, Newark and New York; bacterial examinations by Albany, Buffalo, Denver, Hartford, Lawrence, Newark and New York; and biological examinations by Albany, Brooklyn, Boston, Lynn, Pittsburgh, Buffalo and Wilkesbarre.

There remains a third way in which the contamination of a water supply may be detected, which consists in a sanitary survey, or at least an inspection, of the gathering area. Indeed, in all surface supplies a vigilant oversight of possible sources of contamination should be regularly maintained. Where the area drained is of great extent this may be limited to a careful examination of premises within a few miles of the reservoir or intake and a knowledge of the character of the drainage area—whether cultivated, wooded, rocky and hilly, or otherwise—the population and the general features of the sewerage systems of towns draining thereto. Although a water once contaminated cannot be considered safe even after flowing a great many miles, yet the further the source of contamination the less the danger: first, because in almost all natural streams the effect of dilution will be to decrease the proportion of impurities; secondly, organic matters will, by natural processes become mineralized and pathogenic bacteria die out, and thirdly, because by the sedimentation that is going on more or less at all times organic matter is entrained with the rest and carried to the bottom.

Baumeister has determined the impurities received by sewers (in Europe) to vary from 4.2 to 8.1, averaging 6.7, ounces per capita, about half of which is from human sources; and in order to compare the probable conditions of streams into which systems of sewers discharge he has deduced a formula for what he terms its "coefficient of pollution," which in English measures may be expressed as follows:

Let E = the population on area drained
C = proportion of population tributary to sewers.
Q = discharge of stream in cubic feet per twenty-four hours.
V = mean velocity of stream in feet per second.
P = coefficient of pollution.

Then $P = \frac{Q\,V}{E(1+C)}$

He has used this in arriving at the relative pollution of various European rivers and various points in the same river.

Careful investigations have been made on the sanitary condition of watersheds now utilized for the supplies of Boston, New York, Philadelphia and Pittsburgh. In that of the Delaware watershed made by Mr. Rudolph Hering under the administration of Col. Ludlow, twenty years ago, a map was prepared containing a red dot for every 1000 persons, which illustrated in a very graphic way the relative density of population found in the valleys of the Schuylkill and Lehigh Rivers as compared with those found on the area draining to the Upper Delaware.

The following are the results obtained in several instances:

		Total Area Sq. Mi.	Popula'n per Sq. Mi.
Ohio River(Cincinnati)	1898	75,700	4.56
Croton River	1904	338.8	52
Monongahela "	1900	7,600	24
Allegheny "	1900	11,400	24
Nashua "	1894	118	58*
Mahoning Cr., (Youngstown, O)		967	77

As already stated, the character of a drainage area and that of the stream itself have great influence on the amount and character of its pollution. In a general way, however, it may be said that where the population exceeds 300 per square mile the water will be so contaminated that the supply will not be satisfactory,† while, with a population exceeding 125 per sq. mile, the water is open to suspicion.**

In the absence of available records of population we may assume for every 0.1 part per million of chlorine above the normal, a population of twenty-one persons per square mile of watershed‡—a relation calculated some years ago by Mr. F. P Stearns, now Chief Engineer of the Metropolitan Water Board of Boston.

The intimate relation between density of population and typhoid fever has been shown very clearly and graphically with reference to the Hudson River, by Messrs. Burr, Hering and Freeman in their recent report on a future supply for New

*Exclusive of site of proposed reservoir.
†Rep. Mass. State Board of Health, 1890.
**Dr. S. W. Williston in Rep. Conn. State Board of Health.
‡Examination of Water Supplies Mass. St. Board of Health, 1890.

York by plotting the total population and deaths from typhoid as positive and negative ordinates, respectively, with corresponding abscissas in miles. The typhoid mortality on the drainage area is, therefore, an important factor in the contamination to be expected in a stream.

In a sanitary survey note should be taken of the character and volume of trade wastes, as from tanneries, wool and dye works, breweries, sugar refineries, paper mills, etc.; of the drainage from barn yards, cesspools, fertilized lands and swamps; especially in the vicinity of the intake.

In some cases deterioration of a supply is caused by deposits of organic matter—sludge, sawdust, etc.—in the bed of the stream or reservoir from which it is drawn. But such deposits, the inspector should remember, are not always cumulative, decomposition tending to balance the increment, so that a stable condition of such deposit is no proof that deposition is not constantly taking place. Several centuries ago the Thames was so clogged in this way that large vessels were unable to reach the city of London.

The investigations of Dr. George W. Soper of the possible sources of contamination of the Ithaca supply during the epidemic of 1903 is of interest in this connection as illustrating the grossly unsanitary conditions that can exist on the very outskirts of a University town of above the average character, imperilling the lives of the inhabitants. Of some 14,000 inhabitants 1350 were taken sick and 82 died within about three months. In repeated cases privies were noted draining directly to the water supply of the city. Had these premises been under competent inspection possibly the Water Company would have more fully realized in advance the terrible risks being taken.

The three chief sources of information from which we may form an intelligent opinion of a water supply are, then:

1. The typhoid rate among consumers.
2. Examination of the water itself.
3. Inspection of the watershed with reference to possible sources of pollution.

The first of these should always be watched, the second should be applied at such regular intervals as appear desirable, and the third is of especial value in cases where possible sources

of pollution—especially those of a temporary nature—may exist within several miles of the reservoir or intake. With full information from these three sources those in authority will be enabled to intelligently select and apply such measures to remedy the situation as are proper.

THE REMEDY FOR UNSANITARY CONDITIONS.

Corrective treatment in the case of a polluted water supply may be applied by the individual consumer. He may attach a Pasteur or Berkefeld filter to his faucet, which, if carefully attended to, will remove unwelcome bacteria. He may boil or distill the water, which is safer yet, and then, by adding drops of muriatic acid diluted to 10 per cent. strength and two grains bicarbonate of soda to each gallon, make it again palatable. Or, finally, he may sterilize it by contact with copper—a very simple remedy recently described by Prof. Henry Kraemer in the American Journal of Pharmacy, consisting merely in the immersion in the water of a piece of copper foil about 3½ inches square to each quart tobe purified for from six to eight hours.*

Prophylactic measures left to the option of the individual are always evaded by a large proportion of those most in need of them and are impracticable to enforce. The remedy must be applied on a large scale—to the water supply as a whole. In the remedy, as in the detection of unsanitary conditions, there are three general courses that may be pursued, viz.:

1. The prevention of pollution.
2. The adoption of a pure source of water supply.
3. Purification of an inferior supply.

The question of stream pollution is becoming a very pressing one in the thickly settled parts of this country as it has been for some time abroad. It is one requiring broad and judicial treatment. The questions of a legal and scientific nature that are involved cannot be safely left to popular opinion, even if free from bias. Experience would seem to indicate that responsibility in the preparation and enactment of laws and in their execution should be vested in a competent board or com-

*Sterilization after infection has taken place has been tried successfully by Dr. J. E. Woodbridge by the administration of specific medicines and is of much interest but hardly pertinent to this discussion.

mission, but there is considerable diversity in the ways by which it is sought to control the pollution of water supplies in different states. This is, and should be, undertaken by those directly in charge of water works without dependence on outside aid. Every corporation supplying water to a community should satisfy itself as to its original quality and take measures to avoid any subsequent deterioration that may occur.

In the application of such measures not only sewage but storm water effluents should be diverted from the supply. The anomaly may be noted that, while the activity of its contained bacteria tends to purify water percolating to lower strata the percolation of a good water through a considerable distance of the top soil may cause its deterioration, and that long contact with surface moulds, as in overflowed swamps, is liable to injure a water; so that in constructing reservoirs the top soil is often removed at considerable expense; that very shallow reservoirs, exposing a large surface to both the underlying soil and the heating effect of the sun, are to be avoided, while very deep reservoirs are also objectionable, as the deeper portions cannot avail of the sunlight and air for their purification.

If the area is not too great a regular patrol of the watershed and examination of samples should be maintained, as is done in Brooklyn, Providence and Baltimore.

Unfortunately there are water works where these matters, not being compulsory, are neglected. In this case the value of a competent Health Board becomes apparent, having power to formulate and execute such measures, however drastic, as are required for the public safety.

There is a very great diversity in the composition and authority granted health officials in this country, and much legislation governing these matters is antiquated. In spite of marked differences the State Boards of Health of Massachusetts, Connecticut, New York, New Jersey and Ohio may perhaps be selected as those taking the lead to-day in securing effective results. In Massachusetts, New York and Ohio the local authorities are required to consult with and may receive advice from the State Board, while in the latter, at least, such advice may be mandatory. In the above States and New Jersey and Connecticut the Board is expected to investigate all new supplies and in the case of Ohio this is mandatory.

It is believed that in minor matters the local health officers, or, at most, these and the water works officials by coöperation, will be able to secure proper conditions if given adequate authority. But in matters so vitally related as the sanitary conditions on a watershed and the health of a city's population there should be some central authority in control of both; and this generally takes the form of a State Board of Health, which, as has been remarked, has proven very satisfactory in several States.

In those cases where a supply is taken from a stream heading in or flowing to another State, new complications arise, and so serious may these become that a great city like New York is forced to abandon as a source of supply the one recommended by Mr. John R. Freeman) as that having the greatest advantages—Ten-Mile River in Connecticut—from fear of legislation.

The following opinion rendered on this point by the Committee on Legislation to the Engineering Committee of the Merchants' Association of New York in their comprehensive investigation of the question about five years ago is of interest:*

"In our opinion the City of New York has no right to divert the flow of the Ten-Mile River from the State of Connecticut, nor to divert the flow of the Rampo River from the State of New Jersey, and in case of such diversion of the Ten-Mile River a lower riparian owner on the river in Connecticut could enjoin the proposed diversion in an action either in the United States Courts or in the Courts of New York State."

Also, "We are of opinion that the City of New York cannot acquire any power of preserving drainage basins from pollution in the State of New Jersey, except by purchase."

It is a question whether the difficulties in the case might not have been overcome by compensation to riparian owners or else resort to the Federal Courts if a strong sentiment in favor of this plan had existed among those in authority.

Nevertheless this suggests the desirability of providing interstate regulation in order that an important city may avail itself, if necessary, of far-lying water supplies, though naturally

*The Water Supply of New York, 1900, pp. 452, 476.

tributary to other nearby towns without resort to litigation. The inadequacy of artificial political boundaries is to a certain extent recognized in Great Britain, where officials in control of matters pertaining to stream pollution are given jurisdiction over certain drainage areas instead of a county or other arbitrary area. In the matter of water supplies this plan may in certain cases fail to be quite perfect because areas draining to surface streams and those draining to underground supplies may be far from identical. In a general way, however, jurisdiction extending over drainage areas would appear most feasible and desirable; and in order to adjust questions arising where this area lies in two or more States it is evident that, unless unconstitutional, general control should be vested in some central authority.

In discussing this matter Mr. J. S. Haring has said:* "The only way to make the purification of water supplies effective is to first prevent, by Federal laws, the pollution of rivers and streams. Too many of our rivers are in the jurisdiction of more than one state to make the state control of these matters effective. * * * Only a general law, irrespective of State or city, can prevent effectually what will be in a few years, if it is not in some places already, an evil of great magnitude."

Interstate legislation would fail to overcome difficulties promptly and without friction.

It is suggested that, inasmuch as the U. S. Geological Survey contains a most efficient body of engineers, who have already done a large amount of valuable work in studies pertaining to hydrology, stream flow, stream pollution and artesian well supplies, and is now taking up extensive constructive work in connection with irrigation, it would provide admirably the central authority sought; while interstate disputes could be referred by the Survey to the Federal courts, and matters concerning local pollution left, as at present, to state or local boards of health.

For the application of such a system of control some plan such as the following, suggested several years ago,† might be adopted. This provided:

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*Trans. Am. Soc. C. E., Dec., 1899.
†Trans. Am. Soc. C. E., Dec., 1899.

First, that all streams should be classified according to their permissible contamination as follows:

Class I. Streams far from populous centers and not likely to be used for manufacturing or domestic purposes.

Class II. Streams likely to be used for other than domestic purposes.

Class III. Streams likely to be used for domestic purposes.

And *second*, a responsible officer should then be selected who should supervise and control all sources of pollution throughout the drainage area of every stream in which pollution is restricted by law.

The Survey or the officer in charge should, according to some well-considered plan, fix the limits of contamination in each case. It should also act as referee in questions relating to the appropriation of water supplies by different municipalities so as to secure the most efficient and equitable results, including those relating to the rights to underground supplies.

For condemnation of water rights lying outside the district in which the town or corporation seeking it is located, power would have to be obtained from the central authority.

The present Royal Commission on Sewage Disposal has had this question of the rights to natural supplies referred to it, and has suggested placing all necessary powers with proposed Rivers Boards, each Board to have jurisdiction over a group of drainage areas.

It may be said here that Speaker Nixon of the New York State Assembly has recently proposed a plan quite similar to that mentioned, allotting certain definite areas to each city in its search for water; while Governor Higgins suggests a State Commission to have jurisdiction over all water supplies, their apportionment and protection.

Whether power is vested in a special commission, a Health Board, or otherwise, it should be granted ample authority with funds to enable it to carry out its provisions effectively. It should be brought into close relations with its local agents, and these, in turn, should coöperate so as to secure the best results.

Referring to this State, which has suffered in the past from typhoid in both epidemic and endemic form, the Engineering News says "to put matters plainly (Pennsylvania) is well known among sanitarians to be notably backward in all mat-

ters concerning the protection of the public health" and this is attributed, not to the character of its officers, but to want of liberality in the legislature in granting adequate power to the State Board of Health, to local authorities and to water companies.*

According to Dr. Chapin, of Providence, it is desirable that the township should constitute the unit of sanitary control; that where, is in New England and Ohio, the township is well developed sanitary control is most successful; but that where this is weak—more dependent upon the county organization—as in Pennsylvania and the South—sanitary control is apt to be feeble and ineffective.

As to the personnel of the controlling body I quite agree with Prof. Sedgwick, who says: "The appointment of an engineer of distinction to membership in the State Board of Health (of Massachusetts) * * * in 1886 marked a new epoch in sanitary administration and has been followed by the happiest results. Other States have since followed the example of Massachusetts and with uniform advantage. * * * A good board of health should be very carefully chosen, should include in its membership one or more expert physician, at least one good engineer, and one good business man. Nothing less will answer for any progressive city in which health and decency are rated at their full value."

A reasonable control over the pollution of natural water supplies may be secured by invoking the common law, but statutory legislation is necessary to ensure purity sufficient for domestic purposes. Some of the more usual and important statutory laws prohibit the direct fouling of a supply by excrementicious or other decomposing organic matter, the discharge therein of sewage or other foul liquors, presence of privies, stables, manure heaps, cemeteries, etc., within a certain distance of the shore, or bathing in the waters of a stream or lake used for a water supply. Thorough disinfection of all discharges from those suffering from typhoid on the watershed should be required. Lack of this simple measure is no doubt the cause not only of much typhoid derived from drinking water, but of a considerable dissemination of the disease by

*The State Board of Health has, since writing this, been reorganized with enlarged power, promising effective results in the future.

means of flies and dust in the rural districts; and each additional case there is an additional menace to the water supply.

Quite as important but more difficult to control is the dissemination of typhoid by those who have the disease in so light a form that they are not confined to bed, by the many cases that are not recognized as typhoid or are incorrectly diagnosed, and by convalescents who may unconsciously continue to spread the germs for many weeks after recovery.*

Attention should be directed to the water served in railroad trains. Unfortunately many towns are supplied with water that is positively dangerous to use. If the tanks in a train are filled in such a town travelers over many miles of territory may unwittingly place their lives in jeopardy by drinking it, and if sickness ensues the cause may never be suspected.

To provide the greatest protection to surface supplies some cities have gone so far as to buy up entire watersheds at great cost. In England, Manchester has secured 11,000 acres in this way, Liverpool has obtained authority to buy 22,000 acres and Birmingham 45,000. In Scotland, Glasgow has secured an agreement from the landowners that on 20,000 acres no leases shall be made for building purposes, while nearer at home, Baltimore has been considering the question of acquiring the watershed of its supply from the Gunpowder River.

But aside from legislative control much may be done by those in charge of water supplies by securing possession of and fencing in marginal areas of streams and reservoirs; diverting or even purifying storm water effluents (which are sometimes very foul), by providing and maintaining a suitable depth in reservoirs, by removing vegetation from the water and its shores, draining swamps on the watershed, removing muddy deposits from the bottom and by providing ample storage.

Surface waters undergo a marked improvement in storage under proper conditions, as impurities settle out and bacteria—especially pathogenic bacteria—diminish rapidly in number. As an illustration examinations of the Croton supply have shown an average reduction in bacteria in passing through the Central Park reservoirs of 45 per cent., while a further reduc-

*172 million germs per c.c. have been found in the urine of a typhoid convalescent. See Petruschky in *Centralblatt fur Bakteriologie*, 1898.

tion of 29 per cent. takes place in the mains before reaching City Hall Square. The reduction found in the numbers of Bacilli Coli was even more marked.*

To prevent pollution, then we should seek the aid of the State through legislation and Boards of Health and those in direct charge of water supplies should take such measures as will not only prevent deterioration of such water after taken over into their hands, but, if possible, improve its quality.

With increasing density of population it becomes impracticable to avoid such contamination of surface supplies that they are unfit for domestic purposes. At such a time a stream of Class III (as proposed) would be placed in Class II, and towns depending thereon for a supply would be forced to one of two courses of action—either to seek some new and unpolluted source or to adopt some method of purifying the existing source; and it is believed that the time will come when all large cities will be forced to accept one of these alternatives. Consequently the development of ground water supplies will be more actively and scientifically carried out than heretofore. Already they are utilized to a considerable extent along the coastal plain between New York and Florida and in the Mississippi Valley. The difficulty of securing an artesian supply increases rapidly with its extent so that, although Brooklyn, Camden, Savannah, Galveston, Memphis and other towns obtain a great part of their supply in this way, it is in smaller towns that we find its greatest development. Serious objections sometimes met with are excess of iron, requiring its removal, as at Red Bank, N. J.; excess of soda, which discolors starch so that the water is unsuitable for culinary and laundry purposes, as at Charleston; excess of carbonic acid, by which lead service pipes are attacked, making tin-lined pipe necessary, as at Atlantic City, and a decrease in capacity frequently occurring from the clogging of the strainers. These may all be of so serious a nature as to render recourse to a distant surface supply preferable.

London proposes a water supply from Wales, and Liverpool, Manchester, Glasgow, Boston and New York have gone many miles to secure satisfactory surface supplies.

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*Rep. of Com. on Add'l Water Supply, 1904, p. 380.

A pure natural source is always to be desired, but failing in these there remains the possibility of purifying a polluted supply, usually by filtration. Within the last fifteen years filtration has been placed on a correct scientific basis and is generally accepted as safe and satisfactory if only the works are properly designed and operated.

While Europe has taken the lead in the introduction of filtration, we have probably surpassed her in excellence of design in our most recent works, and in magnitude those of Philadelphia will head the world's list. The adoption of filtration by Albany, Jersey City, Philadelphia, Pittsburgh, New Orleans and Louisville would be a sufficient guarantee of its efficiency if its results in reducing typhoid were not already known.

As alternatives there are boiling, distillation, æration, sedimentation, treatment with ozone and with sulphate of copper. The first two of these are not applicable to a city's supply on account of cost. Either sedimentation æriation—at one time in use here for the Schuylkill water—may improve the appearance and taste, but will not make a polluted water safe. There are several ozone processes, one of which has been in use by the city of New York in sterilizing sewage effluents on one or two of the Croton watersheds for a number of years. It is believed to do this effectively, but that its applicability in any given case will depend on the cost.

The very simple and inexpensive method of sterilization by the use of copper sulphate, suggested by Messrs. Moore and Kellerman, of the Department of Agriculture, and applied with success at Baltimore and elsewhere appears to be of particular value when used judiciously to remove contamination of a temporary character—either for offensive algæ or bacterial impurity. Its effects are marked and rapid. Dr. Moore cites a case* where "a spring, which was accidentally polluted, and which gave rise to over fifty cases of typhoid in less than a week (in which) the use of copper sulphate completely sterilized the water, and it was possible to continue using the spring within five hours."

One part to ten thousand parts of water, it is said, will destroy typhoid and cholera organisms in three to four hours,

*Eng. News, Feb. 9, 1905.

while one part in two million is generally sufficient. Algæ are destroyed by one part of the salt dissolved in from 100,000 parts of water in the case of Beggiatoa to twenty-five million parts in the case of Spirogyra.

Some very noteworthy results were obtained from its use in the polluted water of the Scioto River, supplying Columbus, Ohio.

Previous to treatment the colon bacillus was rarely absent from the water. From August 19th till December 30th, 1904, daily tests showed the samples to be free from this organism. January 5th, owing to alarm caused by the newspapers, treatment was discontinued. The consequent result as shown by the following tabular statement is strong testimony to the value of this method of treatment—at least as a temporary expedient—for the sterilization of an infected water:*

June,	Water not treated	24
July,	" "	33
August,	" treated after the 19th	52
September,	" "	16
October,	" "	16
November,	" "	8
December,	" "	4†
January,	" not treated after the 5th	91
February,	" "	376
To March 27,	" "	279

So far, the Massachusetts State Board of Health has failed to recommend this method for general application, probably through fear that by carelessness so large an amount of copper might be used as to be prejudicial to health, and for this reason it has been recently unfavorably reported in connection with the supply of New York City.‡

To decide whether to adopt a new supply or to improve the

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*Copper as an Algicide and Disinfectant in Water Supplies, Bulletin 76, Bureau of Plant Industry, 1905.

†Seventeen cases reported, but only four used city water.

More recent investigations indicate limits to the efficiency of this treatment, depending on temperature, quality of water, etc. K. A.

‡"If this process be carefully conducted such growths (of algæ) may be safely prevented in this way, but this Commission is decidedly opposed to the use of copper sulphate in the Croton supply, because, remaining in the water, if carelessly introduced, it might endanger the health of consumers. The report of Messrs. Hazen and Whipple contains similar conclusions."

Report on Filtering the Croton Water. Burr-Hering-Freeman, January 16th, 1905.

present one is often a serious question, and one that usually requires the services of the expert engineer. If the present source is not seriously contaminated, and if an artesian supply is available, there is the choice between purification of the former, the development of a ground water supply or of securing a new surface supply. Either may be entirely satisfactory as to quality, and it is probable that a comparative estimate will eliminate one or possibly two from the question. While a surface supply may be said to be always in need of inspection, this is no less of a filter plant; and although artesian wells be considered the safest of all, yet these have been known to receive serious pollution by hidden channels tapping contaminated surface water. It is noticable that while English towns generally depend on protected surface supplies, in Germany filtration is general and in France there is a marked tendency to secure underground supplies. We cannot always secure the ideal supply but must do the best under existing circumstances.

It may be said that no amount of dilution will make a stream once contaminated absolutely safe for drinking purposes; but we must bear in mind that all surface supplies are open to this criticism and, while the trend of public opinion is setting strongly toward filtered or underground supplies it will necessarily be many years before we can hope even to approximate such ideal conditions. We should, however, throw such safeguards about our surface supplies as will ensure the greatest practicable protection. In striving toward our ideals it is wise to consider the cost of each and then secure the greatest possible good with our available funds, leaving if necessary their absolute fulfillment to future generations. In the meantime we need not allow our ideals to fade or be lowered. While placing matters of greatest moment on a monetary basis—if you will—this way of securing the greatest good to the greatest number is, after all, both the scientific one and good common sense; and if a town with but $10,000 to spare can save more lives by providing a pest house or by introducing sewers than by perfecting its water supply, I would say build the pest house or sewers first by all means, and defer the desired improvements to the water supply. It is a business question—a matter of estimate.

DISCUSSION.

DR. HENRY LEFFMANN:—The many difficult problems that confront the municipal hydraulic engineers have been so well presented in the paper that further discussion is unnecessary. I desire to express strongly my approval of the author's endorsement of the value of chemical analysis of water intended for drinking purposes. When, about a quarter of a century ago, bacteriology took a sudden lurch into prominence, it was claimed that it would set aside chemical analysis. Koch said that such analysis is mere ethics. Naturally, it was thought that water-borne diseases are most likely to be due to minute organisms, the detection of which would be possible and sufficient. It soon appeared, however, that these organisms are very elusive, and, after many mistakes and some untruthfulness, bacteriologists are prepared to admit that the most important water-borne disease germ, that of typhoid fever, is practically not discoverable in ordinary waters. For the valuation of well and spring waters, chemical analysis is still essential. The data, chlorine, nitrates and nitrites give us information as to where the water has been and how long ago, points of great sanitary moment. I have long regarded the analysis, bacteriologic or chemical, of surface waters as of little practical value. It seems that each community must learn the lesson for itself, that unfiltered surface water that has been collected or has flowed through even a sparsely-settled district, is unfit for drinking purposes. In discussing the biology of the typhoid bacillus, it must be borne in mind that the researches are made with organisms that have been obtained from human viscera or discharges and not from water. I think that great caution should be observed in applying the biologic data obtained in this way to practical problems in water sanitation.

ARTIFICIAL SILK.

In the Consular Reports issued by the Department of State there has recently appeared an interesting note on the production of artificial silk by Mr. Richard Guenther, Consul-General at Frankfort, Germany, from which the following extract is made:

"For more than one hundred and fifty years efforts have been made to find a cheap substitute for genuine silk. At last cellulose has been found to be suitable for producing brilliant threads of silk-like appearance. The best

kind for the purpose is carded cotton, which was used by Count Hilaire de Chardonnet, the first manufacturer of large quantities of artificial silk.

German chemists, among them Dr. Lehner, of Augsburg, also have solved the problem of making artificial silk. The chief difference between the processes of Chardonnet and Lehner is that the collodion from which the product is made is of a different character, and that in the process of Chardonnet the collodion is spun dry. Dr. Lehner spins his collodion wet and then lets it dry.

The associated factories of artificial silk of Frankfort-on-the-Main, comprising two factories in Germany and two in Switzerland, which have a community of interest with the Chardonnet factory at Besancon, in France, use the process of Chardonnet and Lehner. There is also a company at Elberfeld under the name 'Vereinigte Glanzstoff-Fabriken in Elberfeld,' which owns several factories in Germany and uses the processes of Dr. H. Pauly, Dr. M. Femery, J. Urban, and Dr. E. Bronnert. The last process differs from the other decidedly. Cellulose is dissolved in ammoniated oxide of copper and is then directly separated from this solution by means of an acid in the form of threads.

In order to arrive at a conclusion as to how far artificial silk can replace natural silk in the manufacture of silk goods, it is necessary to compare the physical and chemical qualities of the natural and artificial product. Under the microscope all artificial silks differ from the natural in their greater thicknesses. Tussah silk alone resembles artificial silk. Artificial silks, without exception, possess the quality of at once distending largely in water, which increases their thickness one-third to one-half, while natural silk does not distend perceptibly. This distending seems to be the reason that artificial silk, in a wet state, loses so much in firmness. The artificial silk manufactured by the two associations named shows qualities which come very close to those of natural silk and excels it in some respects.

The product is of an even white color, of a silky touch, and when pressed together has even some of the characteristic crackle of genuine silk, the so-called silky cry. It greatly excels natural silk in brilliancy. The chief use of artificial silk is in the passementerie industry. For passementerie goods and for trimmings it has proven so suitable that for such purposes it is even preferred to natural silk. For embroidering it is the ideal material; its high luster and adaptability to the form of the embroidery add a most brilliant look to such work. In the manufacture of straw hats artificial silk takes the place of straw. The hats made of it excel the ordinary straw hats in brilliancy. A separate branch is that of imitating human hair, called 'meteor,' made of artificial silk. Such imitation hair is as soft as the natural growth and cannot be distinguished from it; it is, furthermore, cleaner and cheaper. The price of natural human hair is often twenty-five times as high as the artificial article, besides the latter is not as heavy as the former. Artificial silk finds to-day an increasing market even in the silk-producing countries."

Book Notices.

Die Darstellung des Zinks auf elektrolytischem Wege. Von. Dr.-ing. Emil Guenther, Hüetten-Ingenieur, Aachen. Mit 59 in den Text gedruckten Abbildungen. (8 vo. pp. xii + 243). Halle a. S. Druck und Verlag von Wilhelm Knapp. 1904. (Price, 10 marks.)

The foregoing volume constitutes the sixteenth of the series of Monographs of Applied Electricity issued by this publisher, nearly all of which have received notice in the *Journal*.

The profitable production of electrolytic zinc has thus far proven to be a most troublesome problem to solve, and much more study and experiment will be required before it is satisfactorily solved. This volume here noticed will be found most useful in giving the investigating reader a complete resumé of the processes thus far proposed for the solution of the zinc problem, and of the results actually accomplished. The profitable solution of this problem would be one of the most important economic achievements in the field of metallurgy. W.

PUBLICATIONS RECEIVED.

Hydrology of the State of New York. By George F. Rafter (New York State Museum, John M. Clarke, Director. Bulletin 85. Economic Geology 12.) Albany: New York State Education Dept. 1905. 8vo., pp. 902. (Price, $1.50.)

Locomotive Testing Plant at the Louisiana Purchase Exposition, St. Louis, Mo. 1904. (Penna. Railroad Co.)

Schiff and Wasser. J. F. Becker, Schiffbauteschnisches Bureau, Hamburg. 1905.

Report of a Fire, Sand and Water Test made upon a 20x22 foot span, hollow tile, grooved arch floor, constructed by the National Fireproof Company at Pittsburgh, Pa. By Ira H. Woolson, M. E. (Price, 25 cts.)

Renold Roller Chain. Booklet No. 54, 1905. Link Belt Engineering Co., Philadelphia 12 pages, illustrations, 8vo.

Armour Institute of Technology Year Book for 1905-1906. Chicago, Armour Institute of Technology Press, 1905. 195 pages, portrait, plan, 8vo.

Geological Survey of Kentucky. Charles J. Norwood, Director. Bulletin No. 1. Preliminary part. The Oil and Gas Sands of Kentucky, by J. B. Holing, Lexington, Survey 1904. 233 pages, illustrations plates, maps, quarto.

Proceedings of the Nineteenth Annual Meeting of the Conference of State and Provincial Boards of Health of North America, Washington, D. C., June 3 and 4, 1904. Providence: Snow & Farnham, 1904. 78 pages, 8vo.

School of Industrial Art of the Pennsylvania Museum. Circular of the School of Applied Art. Twenty-ninth season, 1905-6, Philadelphia. 56 pages, 8vo.

Concrete Steel. A treatise on the theory and practice of reinforced concrete construction. By W. Noble Twelvetrees. With numerous illustrations, designs and tables. 8 vo. pp. xii, 218. Whittaker & Co., London and New York. 1905. (Price, 6 shillings.)

The use of reinforced concrete has, within recent years, worked something of a revolution in engineering construction. This development has received its most active and successful impulse in this country, and it is accordingly a notable circumstance that one of the few contributions relating to the subject should come to us from the press of an English publisher.

W.

Franklin Institute.

(Abstract of Proceedings of the Stated Meeting held Wednesday, September 20th, 1905.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 20th, 1905.

PRESIDENT JOHN BERKINBINE in the chair.

Present, 43 members and visitors.

Additions to membership since last report, 13.

Mr. Lindon W. Bates, of New York, described and illustrated with the aid of models several modifications of the present plans for the construction of the Panama Canal, for which he claimed special advantages. (The communication will appear in the *Journal.*)

Mr. Andrew Wright Crawford and Mr. Frank Miles Day, representing the organizations allied for the acquisition of a comprehensive park system for Philadelphia, presented some interesting data with lantern photographs, exhibiting the present status of the work.

The President expressed the thanks of the meeting to the speakers of the evening, and adjourned the meeting.

WM. H. WAHL, *Secretary.*

Committee on Science and the Arts.

(Abstract of Proceedings of the Stated Meeting held Wednesday, September 6th, 1905.)

MR. SAMUEL SARTAIN in the chair.

Present, nine members.

The following reports were presented and passed first reading:

(No. 2339.) *The Walter Switch.* Dr. B. Walter.

(No. 2366.) *Fuel Saving Furnace and Method.* The Fuel Saving Co., Utica, N. Y.

These reports were held under advisement until the next stated meeting.

The resignation of Mr. Daniel Eppelsheimer, Jr., as a member of the Committee, was presented and accepted, with a vote of regret.

On motion of Mr. L. E. Levy, the Chairman was authorized to appoint a special committee to prepare a memorial of the late John Carbutt, one-time member of the Committee.

WM. H. WAHL, *Secretary.*